ART
Advanced Realtime Tracking

System user manual

SMARTTRACK & DTrack®

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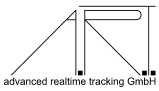		×	×	×

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What's new in version v2.7?

Following, a short overview of the main new features in ***DTrack2*** version v2.7:

- Support for the ***SMARTTRACK*** :
  Introduction of a simplified ***DTrack2*** Frontend for the ***SMARTTRACK***
- Enhancement for the Room adjustment (chapter 4.2.4.4 on page 54):
  one-click adjustment of axes
- Password protection of configurations (chapter 4.2.4.2 on page 46):
  protect important configurations with a password
- Tracking frequency status display (chapter 4.2.1.5 on page 34):
  the status display changes its colour to red in case the effective tracking frequency decreases

Contents

Terms and definitions 7

1 Security advice **8**
1.1 Symbols and their meaning 8
1.2 Safety warnings 8

2 Introduction **11**

3 Markers and targets (rigid bodies) **13**
3.1 Passive markers 13
3.2 Active markers 14
3.3 Standard targets 17

4 System setup **22**
4.1 The *SMARTTRACK* 22
4.1.1 The controller inside the *SMARTTRACK* 25
4.1.2 Setting a static IP address without the *DTrack2* Frontend 26
4.1.3 The setup file 27
4.1.4 The information file 28
4.1.5 Wake On LAN 28
4.1.6 Remote command strings 29
4.2 *DTrack2* frontend software 31
4.2.1 Getting started 31
4.2.1.1 Installation guide (Windows) 31
4.2.1.2 Installation guide (Linux) 32
4.2.1.3 Software update 33
4.2.1.4 Start *DTrack2* frontend software 33
4.2.1.5 Connecting to the *SMARTTRACK* 33
4.2.1.6 Adjustment of the *SMARTTRACK* 35
4.2.2 Room calibration 37
4.2.3 Body calibration 40
4.2.4 Menu structure 45
4.2.4.1 Overview 45
4.2.4.2 Menu DTrack2 46
4.2.4.3 Menu Settings 46
4.2.4.4 Menu Calibration 53
4.2.4.5 Menu Display 57
4.2.4.6 Menu About 58

5 Interaction devices **60**

5.1 Flystick2 . . . 60
5.2 Flystick3 . . . 65

6 General Information **71**
6.1 Service . . . 71
6.2 Cleaning of the equipment . . . 71
6.3 Warranty and liability . . . 71

A Technical specifications **73**
A.1 ***SMARTTRACK*** . . . 73
A.2 Flysticks . . . 74
A.3 Overall system . . . 75

B Radiation Protection for *SMARTTRACK* **76**
B.1 Used Instructions . . . 76
B.2 Classification of the LED Flash . . . 76
B.3 Maximum Permitted Exposure of Radiation (MPER) . . . 76
B.4 Resulting Safety Instructions . . . 77

C Technical Appendix **79**
C.1 Definition of Coordinates and Rotations . . . 79
C.1.1 Room Calibration . . . 79
C.1.1.1 Room Adjustment . . . 79
C.1.2 Body Calibration . . . 80
C.1.2.1 Definition of the Coordinates by the Body itself . . . 80
C.1.2.2 Definition of the Coordinates by the Room Coordinate System, with Origin in the Center of the Markers . . . 80
C.1.2.3 Definition of the Coordinates by the Room Coordinate System, with Origin in a Marker . . . 80
C.1.3 6DOF Results . . . 81
C.1.4 3DOF Data . . . 81
C.1.5 Flystick devices . . . 81
C.1.5.1 Flystick2 . . . 82
C.1.5.2 Flystick3 . . . 82
C.2 Output of Measurement Data via Ethernet . . . 83
C.2.1 Frame Counter . . . 83
C.2.2 Timestamp . . . 84
C.2.3 Standard 6DOF Bodies . . . 84
C.2.4 Flysticks . . . 85
C.2.5 Flysticks (Old Format) . . . 86
C.2.6 Additional 3DOF Markers . . . 86
C.2.7 Additional Informations . . . 87

List of Figures **88**

List of Tables **89**

Index **90**

Terms and definitions

term	definition
3DOF	three degrees of freedom (i.e. only position)
6DOF	six degrees of freedom (i.e. position and orientation)
base	imaginary connecting line between the two integrated cameras of the SMARTTRACK
body calibration	teach the system the geometry of a rigid body
body, rigid body	rigid arrangement of several single markers (see also "target")
calibration angle (410mm or 710mm)	belongs to the room calibration set and defines origin and orientation of the room coordinate system
ceiling suspension	equipment to mount an infrared camera to the ceiling
DTrack2	
backend software	Linux-based software which does all necessary calculations
frontend software	graphical user interface to control the SMARTTRACK
infrared optical tracking	position measurement of bodies (subjects or objects) based upon infrared light and optical measurement procedures
license code (license key)	software key to unlock certain capabilities of the tracking system
marker	object either made of retro reflective material or LED for position tracking (3DOF)
measurement volume	defines the volume where optical tracking is possible
modulated flash	infrared signal which is used for wireless synchronization
mutual blinding	one camera sees disturbing reflections caused by the infrared flashes of another one
room calibration	teach the system the position of each camera and define origin and orientation of the room coordinate system
room calibration set	consists of angle and wand
target	rigid arrangement of several single markers (= rigid body)
tracking	position measurement of bodies that move in a defined space
virtual point cloud	used for calculating the relative positions of the IR cameras
wand	precalibrated stick carrying two markers. The wand belongs to the room calibration set and is used to generate a virtual point cloud and to scale the system

1 Security advice

1.1 Symbols and their meaning

You can find the following symbols and their signification on the equipment or in the manual:

	Useful and important notes.
	Important notes, which may lead to system malfunction or to the loss of warranty by non-observance.
	Important safety warning to assure operation safety. These warnings have to be considered, otherwise user and equipment could be endangered, the equipment could be damaged or the function of the equipment is not warranted.
	Safety warning for infrared radiation. These warnings have to be considered, otherwise users eyes could be endangered.

Table 1.1: Symbols and their meaning

1.2 Safety warnings

Safe operation of the equipment is only warranted if the warnings in this manual and on the equipment are observed.

- Never use the equipment if any part looks damaged.
- Safe operation is not possible, if
  - the housing is damaged,
  - any fluid attains in the housing,
  - objects attain inside the equipment,
  - the equipment shows any visible faults (smoke, sparks, fire, smells, etc.) or
  - the power cord is damaged.
- In any of the cases mentioned above (or similar) pull the power cord out of the power

socket immediately. Otherwise, users or environment are endangered. Please contact the ***ART*** service.

- Never change or alter the equipment, neither mechanically nor electrically. Only the components described by ***ART*** shall be used. The conformity and the warranty of the producer (***ART***) expire by non-compliance.
- Never open the equipment! Only personnel authorized by ***ART*** is allowed to open the equipment. Inside of the equipment there are various hazards like high voltage, electric shocks - even if the equipment is disconnected - which can lead to death on contact. In case of malfunction of the equipment please contact the ***ART*** service.
- Only peripheral devices which meet the safety requirements of EN/IEC 60950 for extra low voltage may be attached on Ethernet-, BNC- and the DC-circuit of the equipment.
- The cameras emit infrared-light flashes which can pose a threat to human health and the environment. Keep enough distance to the flashes of the cameras or the IR flashes. Never look directly into the IR light sources. Carefully read chapter B.
- Be sure that the cameras are firmly mounted in the correct position.
- Do not touch the front pane of the cameras, since the acrylic pane and the lens are highly sensitive surfaces. Be careful to avoid permanent damages (e.g. scratches). Only touch the housings of the cameras.
- The ventilation holes of the ***SMARTTRACK*** must not be covered. Air circulation is necessary to prevent the cameras from overheating. If the air circulation is restricted overheating will damage the cameras. The minimum distance between equipment and environmental objects has to be greater than 3 cm.
- The equipment has to be attached to a power socket with grounding. If the grounding wire is defective the requirement of the safety and the electromagnetic compatibility (EMC) are not guaranteed. To check the function of the grounding wire ask your regional located electrician.
- Before switching on any device, verify that voltage and frequency of your electric installation are within the allowed ranges of the equipment. The characteristics of the equipment can be found on the appliance rating plate or in chapter A. The appliance rating plates are on the equipment's housing (***SMARTTRACK*** on the backside of the housing)
- The power switch on the backside does not completely separate the devices from the electricity network. To completely separate the equipment from the electricity network the power plug must be disconnected from the power socket. The power plug has to be accessible freely. The power socket must be close to the equipment.
- The cabling should be realized such that
  - no one can stumble on the cords,

– the cords cannot be damaged,
– the cords cannot tear down the cameras.

Install a pull relief!

- Only use original ***ART*** (or ***ART*** authorized) components and accessories. Using non-original components or accessories may damage the equipment, cause malfunctions or may void operation safety. The provided components and original accessories can be found in chapters 4 and 5. Only use the originally provided external power supply for operating the ***SMARTTRACK***
- The equipment must not be dropped and/or knocked.
- Do not use any solvents or water to clean the cameras. For more information about cleaning the cameras please read chapter 6.2 on page 71.
- Never expose the equipment to high humidity levels or condensating humidity. Protect the cameras against water and chemicals.
- The equipment must not be operated in environments with intensive formation of dust or hot environments where temperatures rise above 40° C (100° F).

☞ ***ART*** **explicitly denies any liability or warranty if the product is modified in any way or not used according to this manual and the specification labels on the equipment.**

2 Introduction

The ***SMARTTRACK*** is a fully integrated stand-alone infrared optical tracking system. It is designed to be used in small volumes (approx. $2m^3$). In this user manual we are going to perceive "tracking" as measurement of the position of objects or subjects that move in a defined space. These objects or subjects to be tracked have to be equipped with single markers or rigid arrangements of markers (= rigid body or target).

Position and/or orientation of those rigid bodies can be measured. If only the spatial position (X, Y, Z) is measured we call this "three degrees of freedom" (3DOF) tracking. The simultaneous measurement of position and orientation (three independent angular coordinates) is called "six degrees of freedom" (6DOF) tracking.

Single markers are sufficient if only 3DOF coordinates are needed. For 6DOF tracking, a rigid body is mandatory.
Passive markers are covered with retro reflective material - they act as light reflectors. Active light emitters (i.e. based on infrared LEDs) are called active markers.

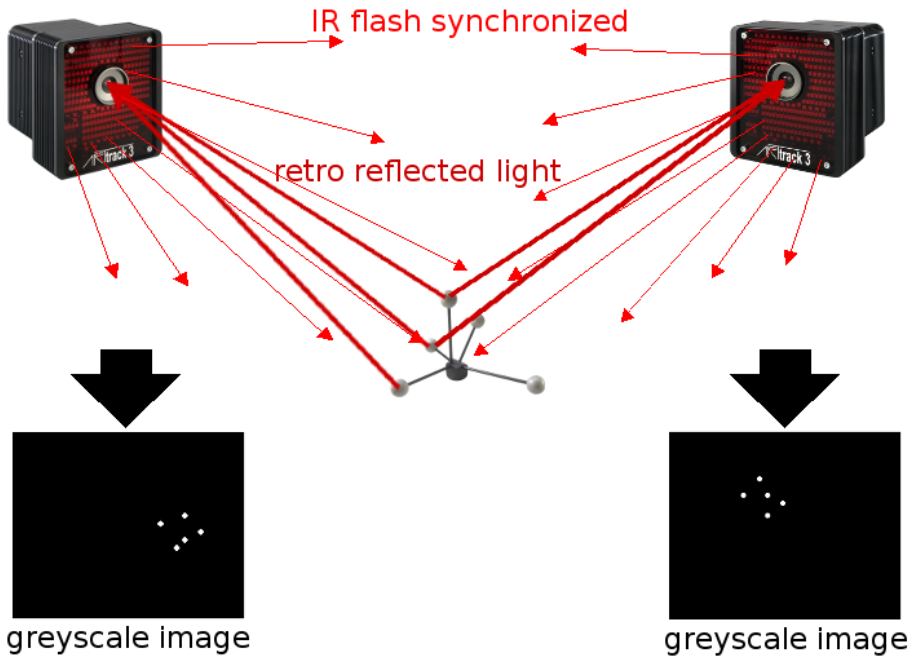


Figure 2.1: Principle of optical tracking (stereo vision)

Figure 2.1 shows the principle of infrared optical tracking with a two-camera system and a standard target. The ***SMARTTRACK*** makes use of the same principle.

The cameras are sending out synchronized IR flashes which are reflected towards the lens by the retro reflective material which is covering the markers of the target. The integrated tracking cameras scan a certain volume, detect the IR radiation that is reflected by the markers and create a greyscale image based on the received IR radiation. The ***SMARTTRACK*** calculates the 2D marker positions with high accuracy using pattern recognition internally. A mean 2D-accuracy of 0.04 pixels (0.1 pixels maximum 2D-deviation) is standard in ***ART*** tracking cameras. Then, based on the 2D data, the ***SMARTTRACK*** calculates 3DOF or 6DOF data. The base for this calculation is that the cameras' field of views are overlapping. ***DTrack2*** calculates the path of the optical rays from the cameras to the markers and delivers the ray intersections in three-dimensional coordinates. These intersections are the positions of the markers.
The position and orientation of the cameras are known from the room calibration. During body calibration, ***DTrack2*** identifies certain marker arrangements as rigid bodies. Based upon this, ***DTrack2*** is able to calculate 6DOF data and, finally, knows position and orientation of the target and, therefore, of the object or subject to be tracked.

In optical tracking systems you have to be aware that tracking is only possible as long as the target is positioned in tracking range of the cameras and is not occluded by any other objects or the object to be tracked. More in detail, at least four markers of a target have to be visible for a minimum of two cameras to enable tracking.

The *SMARTTRACK* has a limited field-of-view and range! It is designed to be used in small volumes. Please refer to chapter 4.1 on page 22 for more information on the tracking volume of the *SMARTTRACK* .

3 Markers and targets (rigid bodies)

3.1 Passive markers

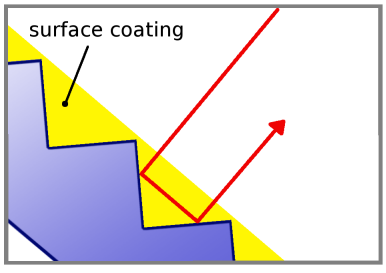
The passive markers used in ***ART*** tracking systems are retro reflectors. These markers reflect the incoming IR radiation into the direction of the incoming light. More precise: the IR radiation is reflected into a narrow range of angles around the (opposite) direction of the incoming light. Passive markers can be either

1. spherical markers:
   - \+ excellent visibility from any perspective,
   - \- expensive fabrication,
   - \- sensitive surface,
   - \- target requires larger volume $\rightarrow$ danger of mechanical damage.
2. flat markers:
   - \+ cheap,
   - \+ flat targets possible,
   - \+ robust surface because cover may be applied,
   - \- the angular range of visibility is limited to approx. $\pm 45^{\circ}$.

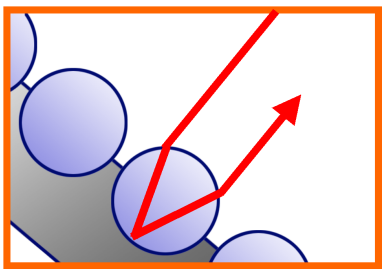
Passive markers are mostly spheres covered with retro reflecting foils. However, they can also be stickers made from retro reflecting material.

Retro reflecting sheets or foils available on the market can be based on two different optical principles:

1. Triple mirrors, which are arranged such that their planes form angles of 90° by pairs, are reflecting light in the described way. Mostly foils with arrangements of many very small mirrors in a plane are used.



2. Glass balls (with a proper refraction index) are focussing incoming light approximately to the opposite surface of the ball. A layer of microscopic glass balls, carried by a reflecting material, acts as a retro reflector. These foils can be fabricated on a flexible carrier material, thus they are widely used for equipping spherical markers with retro reflecting surfaces.



ART spherical markers are covered with retro reflecting foils, based on the glass balls principle.

The quality of the markers decreases when they are in contact with dust, dirt, fat, liquids, glue or comparable contaminants. Please make sure that the markers are not touched or damaged.

3.2 Active markers

Basics Active markers are light (i.e. infrared light) emitting elements, mostly LEDs.

In _ART_ tracking systems four types of LED-based active markers may be used, depending on the application:

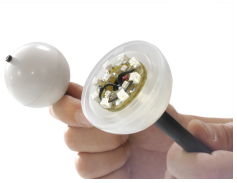
1. Single LEDs without diffusor sphere:

+ can be covered with acrylic protection film,
+ results in simple and robust markers providing visibility up to high distances (up to 10m),
- the angular range of visibility is limited to approx. $\pm 60^{\circ}$.

2. Single LEDs with diffusor sphere:

+ for optimum angular range of visibility,
- distance between marker and tracking camera is limited to a short distance (up to 4.5m).

3. Big active spherical markers:

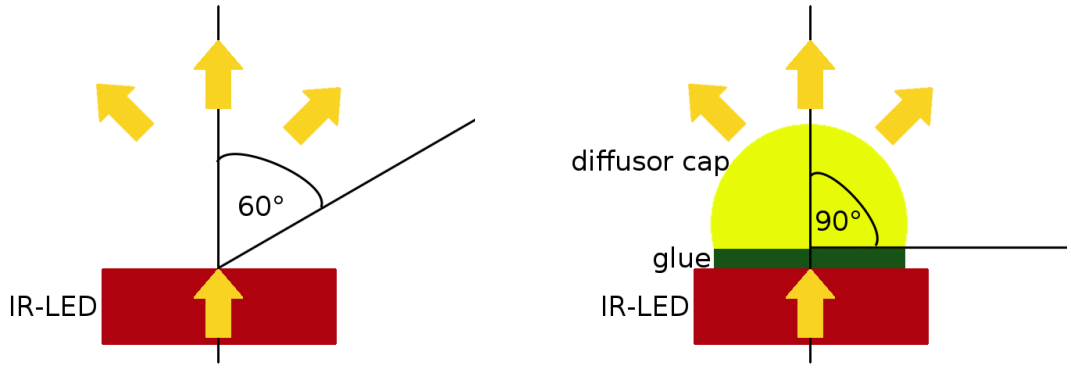


+ several single LEDs per marker, covered with light scattering spheres,
+ provide visibility from all sides and up to very high distances (approx. 20m),
+ suitable for outdoor tracking,
- diameter: 50mm,
- weight: 50g.

4. Big active flat markers:

+ several single LEDs per marker, covered with light scattering surface,
+ tracking up to very high distances (approx. 20m),
+ suitable for outdoor tracking,
+ magnetic base for easy positioning on metal surfaces,
- the angular range of visibility is limited to less than 180°,
- diameter: 30mm.

All active markers provided by ***ART*** are controlled by a special PC board and need power supply.



(a) Single LED (b) Single LED with diffusor sphere

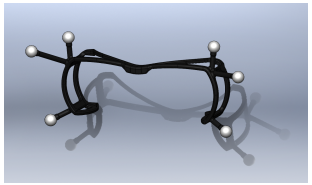
Figure 3.1: Angular range of visibility

Synchronization of active markers Active markers could in principle be activated in CW mode (i.e. continuous light emission). However, this would not be very clever because tracking cameras have a very narrow time slot of sensitivity, i.e. most of the light

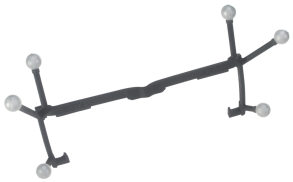
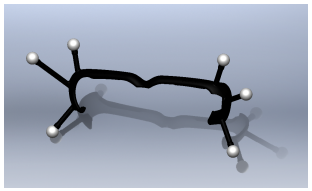
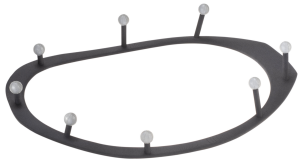
emitted by the markers would be useless for tracking. As a consequence, maximum distance between cameras and marker would be very short due to an upper limit of power dissipation allowed for each single LED. Therefore, all active markers provided by ***ART*** are emitting radiation only when the tracking cameras are sensitive, thus having to be synchronized with the cameras.
Synchronization can be done by a wired connection between the tracking system and the pc-board controlling the active markers, but can also be done in a wireless way.
For wireless synchronization a coded IR flash is being sent out by a tracking camera. The active marker's PC board recognizes the coded flash and activates the LEDs.

3.3 Standard targets

Type	Description	Weight	approx. Dimension	Marker size
Hand target	The hand target is designed for hand tracking in usability and assembly studies respectively. It is also frequently used as a small general-purpose target. Due to the small size this target is easily occluded by the hand carrying it. Therefore, proper arrangement of tracking cameras has to be used in order to avoid occlusions.	25g / 0.9oz	(110 × 80 × 28)mm	12mm
Large hand target	This hand target is designed for hand tracking in a two camera tracking system. Its large size allows to move the hand in almost all directions, without losing tracking.	30g / 1.1oz	(170 × 120 × 35)mm	12mm
Claw target	The claw target looks just the same as the hand target. But it comes in a bigger size and is equipped with bigger markers.	35g / 1.2oz	(160 × 110 × 30)mm	16mm

Type	Description	Weight	approx. Dimension	Marker size
Tree target	Originally designed for tracking HMDs, the tree target is a general-purpose target for tracking from longer distances. It is equipped with 20mm markers.	75g / 2.65oz	(195 × 170 × 120)mm	20mm
Generic glasses target	For head tracking mostly in passive stereo systems, tracking targets must be fixed to the stereo glasses. ***ART*** offers several light-weight standard targets for this purpose.	min: 14g / 0.5oz max: 22g / 0.7oz	(270 × 120 × 35)mm	12mm
INFITEC PREMIUM target 	Target tailored to the INFITEC PREMIUM passive stereo glasses.	26g / 0.9oz	(225 × 85 × 80)mm	12mm

Type	Description	Weight	approx. Dimension	Marker size
CrystalEyes® 2/3 target	Target tailored to the shutter glasses of the StereoGraphics active stereo system. It fits to both CrystalEyes® 2 and 3.	28g / 1oz	(215 × 120 × 60)mm	12mm
CrystalEyes® 5 target	Target tailored to the shutter glasses of the StereoGraphics active stereo system. It fits to the CrystalEyes® 5.	19g / 0.7oz	(195 × 105 × 40)mm	12mm
NuVision APG6000 and APG6100 target	Target tailored to the NuVision APG6000 and APG6100 shutter glasses.	17g / 0.6 oz	(220 × 125 × 75)mm	12mm

Type	Description	Weight	approx. Dimension	Marker size
Volfoni EDGE® target 	Target tailored to the Volfoni EDGE® shutter glasses.	23g / 0.7 oz	(230 × 95 × 60)mm	12mm
NVIDIA 3D Vision® Pro target 	Target tailored to the NVidia 3D Vision Pro shutter glasses.	25g / 0.9 oz	(225 × 100 × 60)mm	12mm
NVisor SX 60 target 	Target tailored to the NVisor SX 60 head mounted display.	55g / 1.94oz	(300 × 215 × 35)mm	12mm

Type	Description	Weight	approx. Dimension	Marker size
Motion capture targets	***ART*** provides a complete set of targets for motion capture purposes. All targets are 6DOF targets and can be identified by the tracking system. A full ***ART*** MoCap target set consists of (subsets can be generated):			
	1 Glasses target (AGT4)	28g / 1.0oz	(225 × 180 × 95)mm	12mm
	2 Shoulder targets (UT)	44g / 1.55oz	(90 × 75 × 35)mm	12mm
	1 Dorsal target (DT)	84g / 2.96oz	(150 × 65 × 35)mm	12mm
	2 Upper arm targets (HBT)	52g / 1.83oz	(150 × 70 × 35)mm	12mm
	2 Forearm targets (UBT)	50g / 1.76oz	(150 × 65 × 35)mm	12mm
	2 Hand targets (HT)	25g / 0.9oz	(110 × 80 × 28)mm	12mm
	1 Waist target (WT, one-piece)	195g / 6.9oz	(390 × 140 × 50)mm	14mm
	1 Waist target (WT, multi-part), each	30g / 1.1oz	(90 × 60 × 50)mm	16mm
	2 Upper leg targets (FBT)	99g / 3.49oz	(220 × 120 × 40)mm	16mm
	2 Lower leg targets (TBT)	58g / 2.05oz	(205 × 70 × 35)mm	16mm
	2 Foot targets (FT)	65g / 2.29oz	(95 × 105 × 70)mm	16mm

Table 3.3: Standard targets overview

4 System setup

4.1 The *SMARTTRACK*

Do not look directly into the *SMARTTRACK* from short distance (< 10cm) for a longer period of time (> 10sec)! Please refer to chapter B on page 76 for more information.

Description The ***SMARTTRACK*** is a fully integrated stand-alone infrared optical tracking system. It is designed to be used in small volumes of approx. $2m^3$.

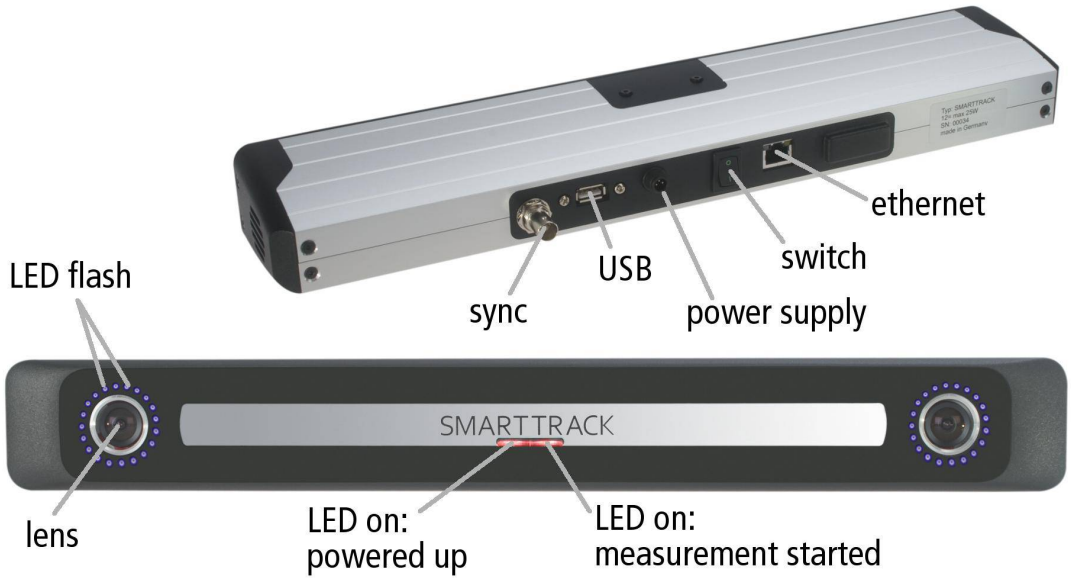


Figure 4.1: ***SMARTTRACK***

Tracking volume

Mounting The ***SMARTTRACK*** is optimized for a predefined measurement volume. System operation in smaller or bigger measurement volumes can lead to reduced accuracy or other malfunctions. The measurement volume can be adjusted within certain limits simply by changing the flash intensity of the ***SMARTTRACK*** (see chapter 4.2.4.3 on page 47).

The tracking system is very sensitive to camera movements. Therefore, the cameras have to be mounted in a way that reduces camera movements (especially vibrations) as much

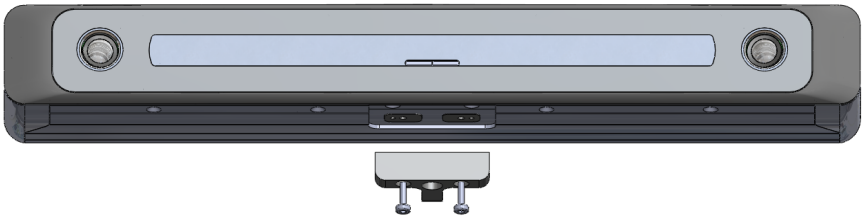


Figure 4.2: Attaching the T-piece to the *SMARTTRACK*

as possible.

Mounting on tripods may be sufficient for presentations and preliminary installations, but is not recommended as a final solution!

Feel free to contact *ART* in case you want to realise a more complex installation. We will assist you in your planning.

Make sure you install the system in a way that you can easily access the *SMARTTRACK* and its cables. Be especially careful to fix it firmly so it cannot fall off.
If the *SMARTTRACK* is falling down it will be damaged and it exposes a danger to humans and the environment.

Avoid hard shocks! A new camera calibration at the *ART* facilities might become necessary in that case.

The cabling should be performed such that

- no one can stumble on the cords,
- the cords cannot be damaged,
- the cords cannot tear down the cameras,
- the line of sight of the camera is not disturbed.

Inappropriate cabling may imply dangers to both, people and equipment. Cable ducts or fixings should be used and a pull relief should be installed!

To avoid measurement problems, no light sources or highly reflecting areas should be visible to the camera. Especially strong point light sources like e.g. halogen lamps and direct or reflected sunlight may imply problems for the measurement (fluorescent lamps are ok).

The T-piece for the *SMARTTRACK* can be attached on both bottom and top side (see figure 4.2).

Only use screws supplied with the carrier for mounting it.

You shall never unfasten other screws of the ***SMARTTRACK*** (see chapter 1.2 on page 8). Otherwise, the ***SMARTTRACK*** may be damaged and liability and warranty is void.

Furthermore, please make sure the ventilator holes are not covered.

Please refer to 4.2 to learn how to install the ***DTrack2*** frontend software.

4.1.1 The controller inside the *SMARTTRACK*

The ***SMARTTRACK*** is an integrated tracking system. That means, inside the small housing we integrated not only two tracking cameras but also the Controller which performs all calculations and generates the data output stream.

The software ***DTrack2*** consists of frontend and backend software. The frontend software is installed on a remote PC which is connected to the ***SMARTTRACK*** via Ethernet. A GUI for easy handling enables the user to control the tracking system completely from the remote PC. The benefit is that the system becomes more flexible, i.e. different users can control the tracking system at any one time (but not simultaneously!) from different working places.

Furthermore, ***DTrack2*** provides the possibility to control its functions via Ethernet (i.e. without the ***DTrack2*** frontend software). This is done by establishing a TCP/IP connection with the ***SMARTTRACK*** and exchanging short command strings (refer to chapter 4.1.6 on page 29). Please contact ***ART*** if you are interested in using this feature.

The backend software, which is Linux-based, runs on the integrated ATC - all necessary calculations (3DOF, 6DOF data, ...) are done by it. The data and control commands are interchanged via a TCP/IP connection between the ***SMARTTRACK*** and the ***DTrack2*** frontend software on the remote PC. Data output to the application or graphics workstation is done via a UDP connection.
Interaction devices have to be connected to the respective ports of the ***SMARTTRACK*** (refer to chapter 5 on page 60).

The ***SMARTTRACK*** is equipped with an input for an external synchronization signal (rectangular or video sync signal). The signals for external synchronization are transferred via BNC connections.

The external sync input is not internally terminated.
When synchronizing with a video input, a T-piece with an external 75Ω terminating resistor should be used if the signal line ends at the *SMARTTRACK* .
When using a TTL-signal you should not use a terminating resistor. However, you should use a shielded cable for the synchronization with a TTL-signal.

By default, the ***SMARTTRACK*** is set up to support DHCP. Connect the Ethernet cable to your local network and connect the power supply. If you want to set a specific static IP address before booting the ATC please refer to chapter 4.1.2 on page 26 for more information.

Press the switch on the back to start the ***SMARTTRACK*** . If it is booting without connected Ethernet cable it will use its standard IP address.

The fall-back IP address of the *SMARTTRACK* is 192.168.0.1 (subnet mask 255.255.255.0)!

You may configure another static IP address as follows:

- select *Settings* → *Controller*
- untick the checkbox *DHCP client*
- enter *IP address* and *subnet mask*
- optionally, enter *gateway* and *nameserver*
- reboot the ***SMARTTRACK*** for the changes to take effect

☞ **Please make sure to remember these settings. Otherwise, your *SMARTTRACK* may become unreachable due to wrong IP settings! Refer to chapter 4.1.2 on page 26).**

Finally, start the ***DTrack2*** frontend software on the remote PC. Please refer to chapter 4.2 on page 31 for more details.

4.1.2 Setting a static IP address without the *DTrack2* Frontend

It is possible to configure the IP address of the ***SMARTTRACK*** without the ***DTrack2*** frontend software. You only need a standard USB stick (FAT32 formatted) on which you save a setup file (format see below).

- Plug in the USB stick. It doesn't matter if the ***SMARTTRACK*** is up and running or not.
- If necessary start up the ***SMARTTRACK*** .
- Wait some time (approx. 20-30 seconds) for the ***SMARTTRACK*** to write the two files onto the USB stick.
- Unplug the USB stick.
- Now, you may view the information file or edit the setup file with any editor (instructions given in the setup file).
- In case you changed the setup file, please plug in the USB stick to the ***SMARTTRACK*** again.
- Wait some time (approx. 20-30 seconds) for the ***SMARTTRACK*** to read the setup file.
- Shut down and restart the ***SMARTTRACK*** for the changes to take effect.

Now, your ***SMARTTRACK*** is configured according to your requirements.

4.1.3 The setup file

This file is used to configure the ***SMARTTRACK*** without using the ***DTrack2*** frontend software regarding three parameters, which are:

- configuring the ***SMARTTRACK*** to be a DHCP client,
- setting a static IP address and
- carrying out a factory reset.

Carrying out a factory reset will result in the loss of all your settings!

Following, a description of the file (e.g. smarttrack00007_setup.txt) format:

```
 1# ARTtrack Controller Setup:
 2
 3
 4# ethernet settings:
 5#  - uncomment just one of the lines starting with 'SETNET'
 6
 7# ethernet settings: DHCP
 8#  - uncomment the following line to activate DHCP
 9#SETNET="dhcp"
10
11# ethernet settings: fix IP address and subnet mask
12#  - uncomment the following line to set a fix IP address and subnet mask
13#SETNET="ip 192.168.0.1 255.255.255.0"
14
15# factory reset of all other settings:
16#  - CAUTION: use with care, all your settings will be lost!
17#  - uncomment the following line to reset all other Controller settings
18#RESETSETTINGS="yes"
```

Example:
If you wanted to setup a static IP you would have to remove the '#' sign and enter the desired IP address, here for example: 123.123.0.1

before:

```
13#SETNET="ip 192.168.0.1 255.255.255.0"
```

after:

```
13 SETNET="ip 123.123.0.1 255.255.255.0"
```

4.1.4 The information file

This file contains the current settings of the ***SMARTTRACK*** . Following, a description of the file format (e.g. smarttrack00007_info.txt):

```
ARTtrack Controller Information:

Serial Number     : 00007

Ethernet (LAN)    : dhcp
Ethernet IP (LAN) : 10.10.5.22 255.255.0.0 10.10.0.253
Ethernet MAC (LAN): 00:24:1D:00:C3:B3
```

4.1.5 Wake On LAN

The ***SMARTTRACK*** is capable of Wake On LAN (WOL) if it has been forced into standby mode before by the user (***DTrack2*** → *ARTtrack Controller standby*).

There are two options for waking up the controller remotely:

1. you may use ***DTrack2*** or
2. use a separate tool (Windows: WOL program; Linux: console-based command).

Option 1 - WOL via *DTrack2* Start the ***DTrack2*** frontend software as usual. The '*Connect*' button will change its name into '*Wake On LAN*' (refer to figure 4.3).

Figure 4.3: Welcome screen of ***DTrack2*** with Wake On LAN option

Please make sure that the *SMARTTRACK* is still connected to the local network! *DTrack2* cannot wake it up if no physical connection between remote PC and *SMARTTRACK* is established!

Press the '*Wake On LAN*' button and ***DTrack2*** is trying to wake up the ***SMARTTRACK*** - this may take up to two minutes as the ***SMARTTRACK*** has to boot up (see figure 4.4).

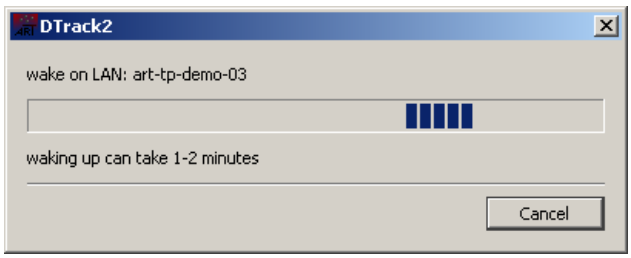


Figure 4.4: Wake On LAN progress bar

If Wake On LAN was successful ***DTrack2*** will automatically establish the connection with this ***SMARTTRACK*** and start the frontend software.

Option 2 - WOL via separate tool You will need the hostname of the ***SMARTTRACK*** as well as its MAC address. To get this information, please press *Settings* → *Controller* and remember the '*hostname*' and its MAC address ('*ethernet-MAC LAN*').

If you are a Windows user you need a separate WOL program to use this feature. Please refer to the manual of the WOL program you are using to find out how to configure the WOL function.

When using Linux you only need to switch to the console and type in the following command and your ***SMARTTRACK*** restarts:

for Linux openSUSE:

```
$ wol <MAC address of your SMARTTRACK>
e.g.: $ wol 00:1D:92:3A:58:5F
```

for Ubuntu:

```
$ wakeonlan <MAC address of your SMARTTRACK>
e.g.: $ wakeonlan 00:1D:92:3A:58:5F
```

4.1.6 Remote command strings

The following commands may be used in combination with the ***DTrack2*** SDK to control the tracking system remotely (e.g. with your media control) and without the ***DTrack2*** frontend. The ***DTrack2*** SDK is available from ***ART*** upon request.

Command string (always preceded by "dtrack2")	**Description**
tracking start	Start the measurement
tracking stop	Stop the measurement
set config active_config <name>	Change the configuration to <name>
set output net <channel id> udp <host> <port> *example: dtrack2 set output net ch02 udp 231.231.0.1 5003*	Configure where the data has to be sent to
set output net <channel id> multicast <host> <port> *example: dtrack2 set output net ch02 multicast 231.231.0.1 5003*	Configure where the data has to be sent to
set output active <channel id> <output type> <yes/no> *example: dtrack2 set output active ch02 all yes*	Activate or deactivate the data output and specify the data to be transmitted
system shutdown	Force the ***SMARTTRACK*** to go into standby

4.2 *DTrack2* frontend software

The software ***DTrack2*** is intended to run on a remote PC (Windows or Linux). The ***SMARTTRACK*** can be controlled remotely via Ethernet. The software ***DTrack2*** itself is delivered via CD-ROM.

☞ ***DTrack2* supports the *SMARTTRACK* starting with version v2.7.0. Please don't use it with older versions of the *DTrack2* frontend software.**

4.2.1 Getting started

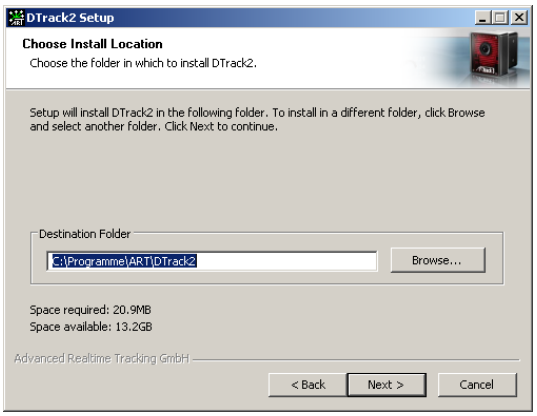
Please refer to chapter A.3 on page 75 for more information on supported operating systems.

4.2.1.1 Installation guide (Windows)

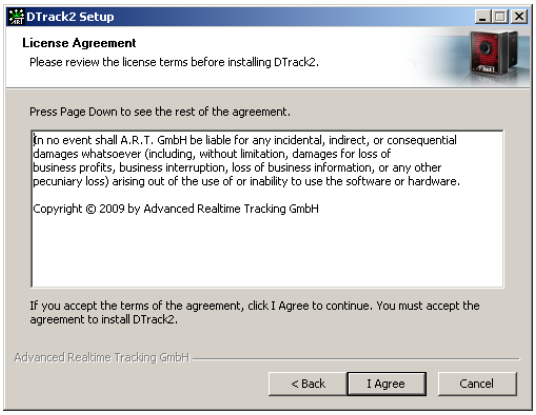
Run the installation executable "*DTrack2_v2.x.x_win32_install.exe*" and the installation wizard of ***DTrack2*** starts.

DTrack2 Setup
Welcome to the DTrack2 Setup Wizard
This wizard will guide you through the installation of DTrack2.
It is recommended that you close all other applications before starting Setup. This will make it possible to update relevant system files without having to reboot your computer.
Click Next to continue.
advanced realtime tracking GmbH
Next >
Cancel

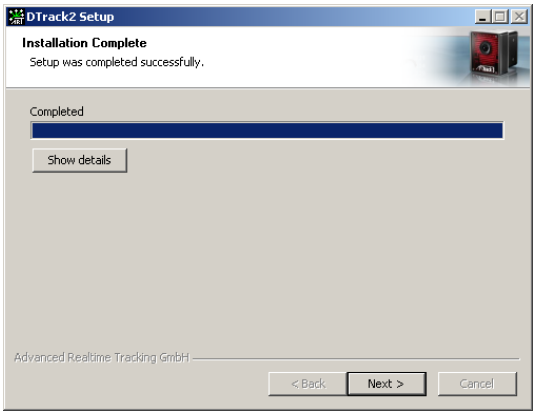
Click *Next* to continue and to start the installation process for ***ART DTrack2*** software. Administrator rights are not necessary.


DTrack2 Setup
Choose Install Location
Choose the folder in which to install DTrack2.
Setup will install DTrack2 in the following folder. To install in a different folder, click Browse and select another folder. Click Next to continue.
Destination Folder
C:\Programme\ART\DTrack2
Browse...
Space required: 20.9MB
Space available: 13.2GB
Advanced Realtime Tracking GmbH
< Back
Next >
Cancel

Now, please choose the destination folder in which you want to install ***DTrack2*** .


DTrack2 Setup
License Agreement
Please review the license terms before installing DTrack2.
Press Page Down to see the rest of the agreement.
In no event shall A.R.T. GmbH be liable for any incidental, indirect, or consequential damages whatsoever (including, without limitation, damages for loss of business profits, business interruption, loss of business information, or any other pecuniary loss) arising out of the use of or inability to use the software or hardware.
Copyright © 2009 by Advanced Realtime Tracking GmbH
If you accept the terms of the agreement, click I Agree to continue. You must accept the agreement to install DTrack2.
Advanced Realtime Tracking GmbH
< Back
I Agree
Cancel

Please read the license terms carefully and press *I Agree* if you agree indeed. A new window shows the installation progress.



The installation of the ***DTrack2*** software is complete now. ***DTrack2*** has been installed on your computer. Click *Next*.

Press *Finish* to complete the ***DTrack2*** setup wizard. Now, you can use ***DTrack2*** .

4.2.1.2 Installation guide (Linux)

The software is packed in an archive (*DTrack2_v2.x.x_linux32.tar.gz*). You do not need to have administrator rights to extract all files to a user-defined folder. In a shell, change to the user-defined folder and type in the command `tar xvf DTrack2_v2.x.x_linux32.tar.gz` in order to extract the files. For ease of use, you may create a shortcut on the desktop.

DTrack2 can be started with the command `./DTrack2`.

☞ **The *DTrack2* frontend software for Linux is a 32 Bit application. If you are running a 64 Bit Linux please install all 32 Bit extensions for your distribution.**

4.2.1.3 Software update

Please contact ***ART*** in order to receive the latest ***DTrack2*** software. For the installation of the update, please proceed as mentioned before in chapters 4.2.1.1 and 4.2.1.2.

4.2.1.4 Start *DTrack2* frontend software

When you start ***DTrack2*** on the remote PC you will see the following start window (see figure 4.5).

Figure 4.5: Welcome screen of ***DTrack2***

4.2.1.5 Connecting to the *SMARTTRACK*

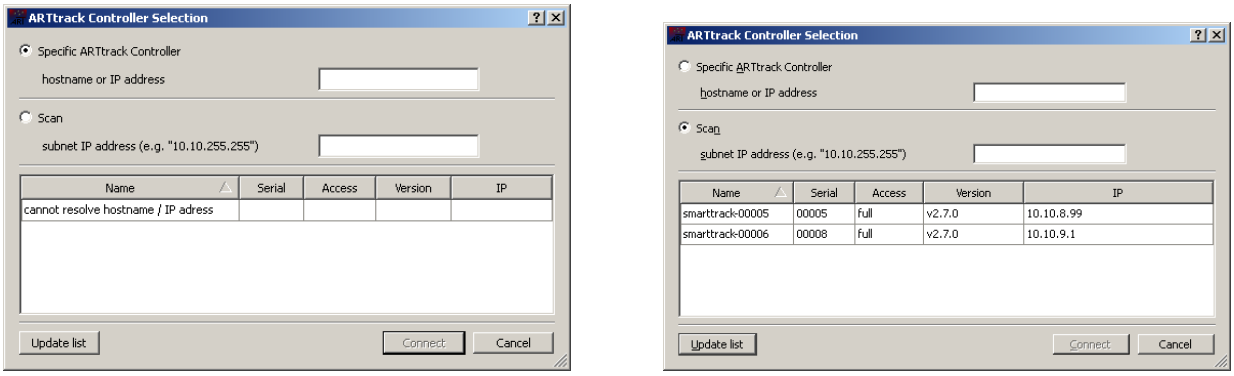
The first time you start ***DTrack2*** , no default ***SMARTTRACK*** will be found and another window will be opened automatically (see figure 4.6). The radio button at position *Specific ARTtrack Controller* will be ticked.

If you know the name (typically like "smarttrack-00001") or IP address of your ***SMARTTRACK*** you may enter it in line *hostname or IP address* and press *Connect*.

Otherwise, you can select *Scan*, if you don't know the hostname or the IP address of your ***SMARTTRACK*** . You will see a list of the available ***SMARTTRACKs*** in your network.

In column *Name* every ***SMARTTRACK*** in your network will be listed. If no ***SMARTTRACK*** or not the desired ***SMARTTRACK*** is listed there please press *Update list*. Now, the list should contain your desired ***SMARTTRACK*** .

You can identify the correct ***SMARTTRACK*** by comparing the serial number on the label on the back of the ***SMARTTRACK*** with the serial number listed in this window (column



(a) specific ATC (b) scan the network

Figure 4.6: ***ARTTRACK*** Controller Selection

Serial). ***SMARTTRACKs*** set in grey are used by other PCs in the network (→ IP address listed at the bottom of the welcome screen). It is only possible to connect to ***SMARTTRACKs*** set in black. Select the entry which fits to your desired ***SMARTTRACK*** and press *Connect*.

The next time you start ***DTrack2*** your ***SMARTTRACK*** is still known by the software and ***DTrack2*** automatically searches for it. The welcome screen shows the name of your ***SMARTTRACK*** . If this is the one you want to connect to, just press *Connect*.

The graphical user interface The graphical user interface of ***DTrack2*** offers different views which can be switched on and off by the user:

1.	Monitor 2DOF	Graphical display of markers seen/tracked by the cameras. Colour code signifies the circularity or the size of the markers, respectively.
2.	Event Display	Displays ***DTrack2*** events (e.g. "no valid room calibration")
3.	Data Display	Displays measurement results (6DOF and/or 3DOF)
4.	Flystick	Shows the measurement results (6DOF and/or 3DOF) and the operation of the buttons and the joystick
5.	Measurement Tool	Shows the measurement results of the Measurement Tool and, if assigned, the reference body

By default the first three are shown (see figure 4.7).

In the status bar, a button for starting and stopping of the measurement is integrated. Additionally, you may retrieve information regarding the cameras connected, the synchronization frequency, the number of bodies tracked and the number of single markers seen.

The synchronization frequency field is changing its colour to yellow, orange and red in case the effective frequency is decreasing (see figure 4.8):

- grey: max. 5 frames per minute lost (i.e. 3600 frames per minute are transmitted)
- yellow: 5 - 10 frames per minute lost

- orange: 10 - 15 frames per minute lost
- red: > 15 frames per minute lost

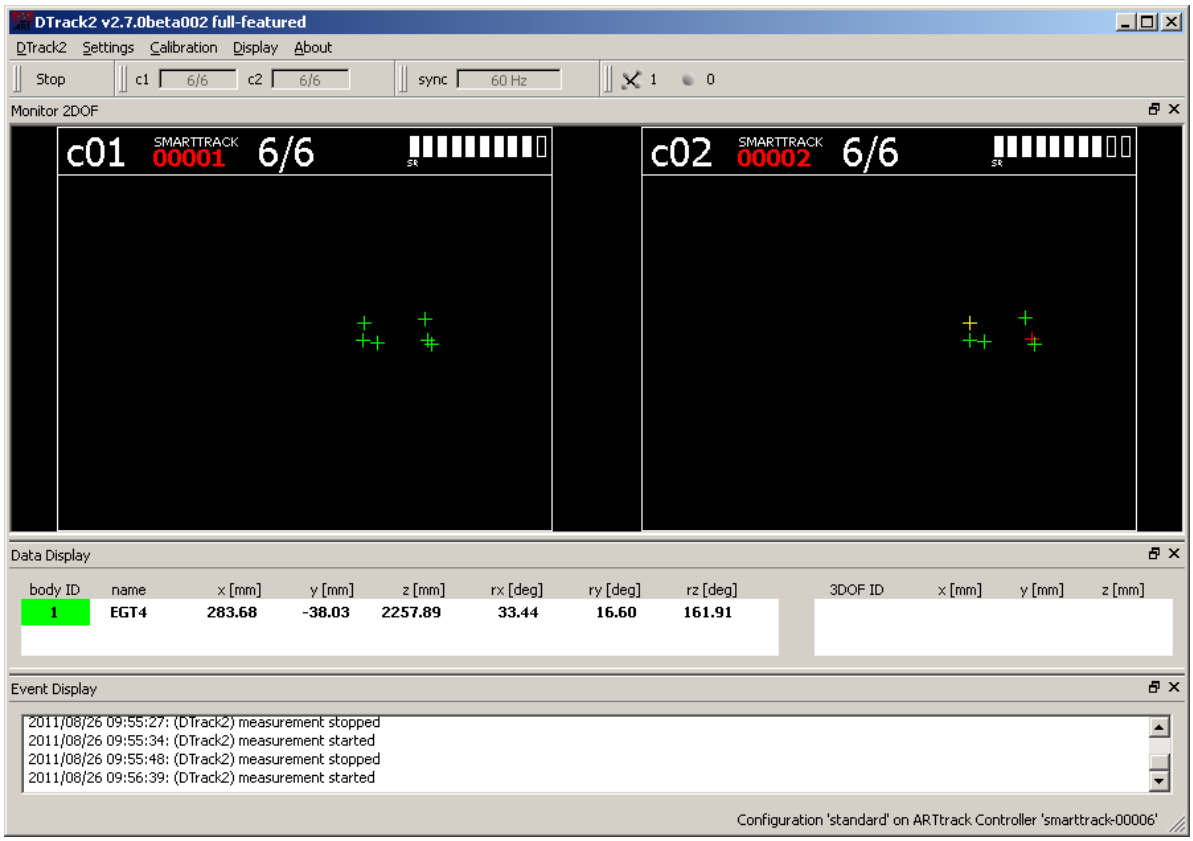

DTrack2 v2.7.0beta002 full-featured
DTrack2 Settings Calibration Display About
Stop
c1 6/6 c2 6/6
sync 60 Hz
1 0
Monitor 2DOF
c01 SMARTTRACK 00001 6/6
c02 SMARTTRACK 00002 6/6
Data Display
body ID name x [mm] y [mm] z [mm] rx [deg] ry [deg] rz [deg]
1 EGT4 283.68 -38.03 2257.89 33.44 16.60 161.91
3DOF ID x [mm] y [mm] z [mm]
Event Display
2011/08/26 09:55:27: (DTrack2) measurement stopped
2011/08/26 09:55:34: (DTrack2) measurement started
2011/08/26 09:55:48: (DTrack2) measurement stopped
2011/08/26 09:56:39: (DTrack2) measurement started
Configuration 'standard' on ARTtrack Controller 'smarttrack-00006'

Figure 4.7: Graphical user interface of *DTrack2*

(a) yellow: 5 - 10 frames per minute lost

(b) orange: 10 - 15 frames per minute lost

(c) red: > 15 frames per minute lost

Figure 4.8: Visualization of the synchronization frequency decrease

4.2.1.6 Adjustment of the *SMARTTRACK*

So far, the ***SMARTTRACK*** has been mounted and connected to the remote PC either directly or via a network.

Now, adjust the ***SMARTTRACK*** in a way that allows to cover the desired measurement volume as good as possible. To check that, ***DTrack2*** provides the *Monitor 2DOF display* that essentially is a graphical display of the field of view of the ***SMARTTRACK*** and of the

markers that are seen by it (presented two-dimensional).

As the ***SMARTTRACK*** is pre-calibrated there's basically not much more to do - you can start tracking right away. If you need to arrange the coordinate systems of the tracking system and the application software you'll have two possibilities:

1. within ***DTrack2*** go to *Calibration* → *Room adjustment* (refer to 4.2.4.4 on page 54), or
2. adjust the values within the application software.

Monitor 2DOF display The Monitor 2DOF view shows two black windows for the integrated IR cameras (equivalent to the field of view) with a schematic display of positions and sizes of all recognized markers. A simple colour code signifies the size and the circularity of the markers (green = very good quality, yellow = good quality, red = bad quality).

As a rule of thumb, for measurement applications with high accuracy requirements the markers should be displayed in green; for VR applications yellow markers are always ok. The Monitor 2DOF display is particularly useful for the final adjustment (especially orientation adjustments) of the ***SMARTTRACK*** .

Additionally, the intensity of the brightest pixel in the field of view is shown using a bar display (refer to figure 4.7).

A click with the right mouse button into one of the windows opens a menu (see figure 4.9) with settings for the respective camera.

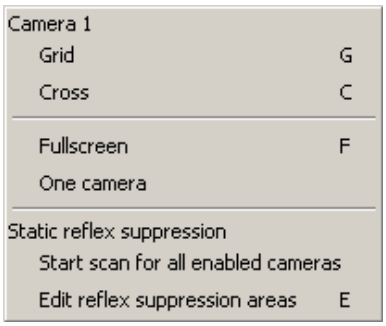


Figure 4.9: Monitor 2DOF view menu (e.g. camera 1)

By clicking and holding the left mouse button on one of the camera displays, its position can be moved within Monitor 2DOF view.

A more detailed description of the features of the *Monitor 2DOF view* can be found in chapter 4.2.4.5 on page 57.

4.2.2 Room calibration

The *SMARTTRACK* is pre-calibrated and, therefore, it is usually not necessary to perform a room calibration.
Although we will protect the *SMARTTRACK* as good as possible before shipment, it may occur that environmental conditions during shipment have an impact on the room calibration of the *SMARTTRACK* (e.g. temperatures below -30°C or severe vibrations). Then, a room calibration will be necessary.

However, it will still be possible to perform a room calibration with the ***SMARTTRACK*** in case you experience a degradation of tracking performance or if you want to obtain a special orientation of the room coordinate system.

During the room calibration, the system determines the three-dimensional coordinate system.

In principle, it is recommended to always perform a room calibration after a certain operating time of the system, especially if the system setup does not exclude camera movements over time (these camera movements may also be thermal drifts!).

For room calibration, the calibration angle of the "room calibration set" is inserted anywhere into the field of view of the ***SMARTTRACK*** . By default, the origin of the calibration system lies centered between the two status LEDs in the front. The orientation is as shown in figure 4.10.

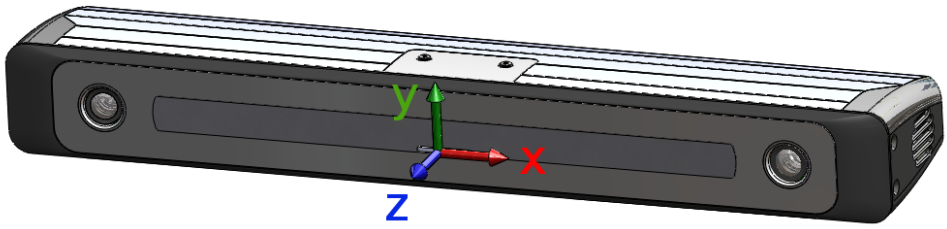


Figure 4.10: Origin of the room coordinate system (default)

Within ***DTrack2*** 's Monitor 2DOF display, which is started in the background when selecting *Calibration* → *Room*, you can verify that all markers of the angle are seen by the ***SMARTTRACK*** .

The longer arm of the angle defines the X axis (refer to figure 4.12); the shorter one the Y axis. The center of marker #1 defines the origin of the room coordinate system (at a height of 15.5mm).

The pre-calibrated stick carrying two markers is called the "wand". Its function is to create a virtual "point cloud" in the measurement volume that is used for calculating the room calibration with high accuracy. Furthermore, the wand is scaling the system. That's why damages of the wand (loose markers, bent poles, etc.) lead to miscalculations of the measurement volume.

The room calibration dialogue allows the input of the wand length and marker quality, as well as the calibration duration.

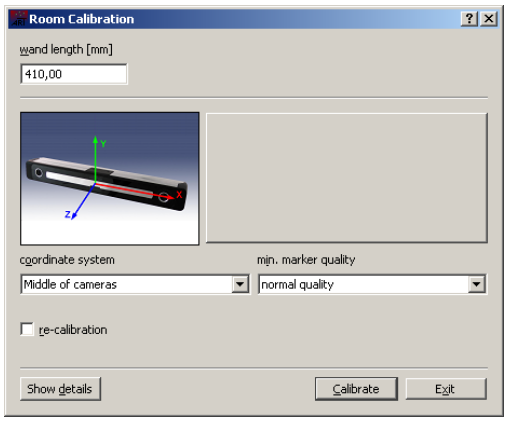


Figure 4.11: Room calibration settings (e.g. RCS 410)

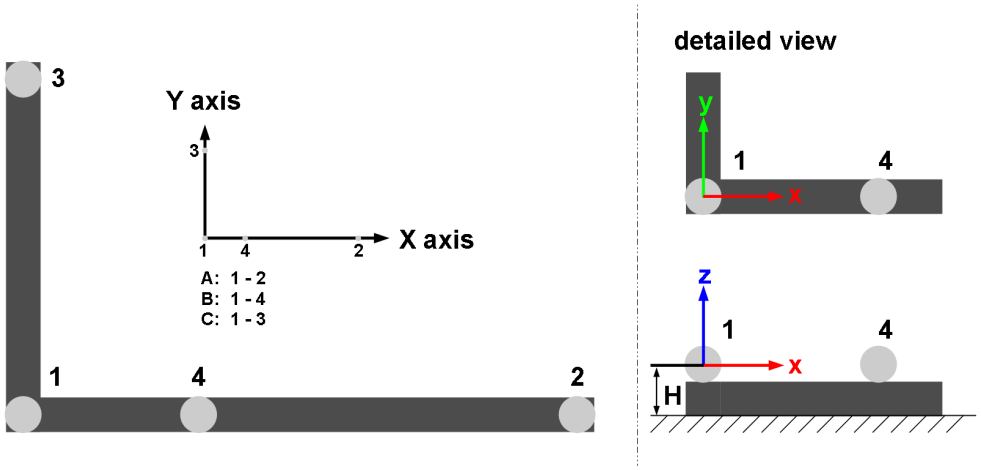


Figure 4.12: Marker distances (including numbering) on the angle and definition of room coordinate system

The wand length has to be set manually in this dialogue - it is written on the label of the wand.

Incorrect input data for this dialogue will lead to a poor room calibration, to wrong system scaling, or to an abortion of the whole room calibration process.

If the default orientation and position of the coordinate system (i.e. '*Middle of cameras*', see figure 4.10) is not adequate for your application you may select an alternative from the list at the bottom of the dialogue. Then, you'll define how the coordinate system of the room is created relative to the calibration angle (refer to table 4.1).

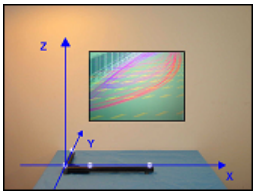
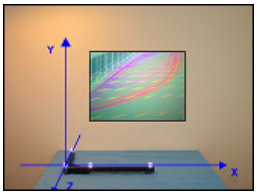
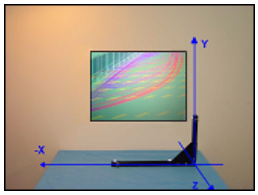
Standard	**Powerwall**	**Powerwall standing**
		
In the *Standard* setting the angle defines the X/Y plane (X at the long, Y at the short beam) and Z upward.	With the *Powerwall* setting the X/Y plane is in the screen and the Z axis pointing out of the screen. This is the standard screen coordinate system of many VR systems (e.g. OpenGL, TrackD, etc.).	With the *Powerwall standing* setting the same coordinate system as in the *Powerwall* setting is created. However, the angle tool must be positioned vertically parallel to the screen.

Table 4.1: Options for coordinate system definition

The allowed marker quality for the calibration can be chosen in a selection box. If the quality of measured markers is worse than the chosen quality, these markers will not be used for the calculation of the room calibration. The default setting for the quality of the markers is '*normal quality*' and should only be changed by experienced users. For example, choosing '*any quality*' may allow room calibration in critical situations where standard settings would lead to calibration failure. However, the quality of the room calibration will be poor.

If you don't succeed in performing a successful room calibration with the '*normal quality*' setting, please contact *ART* !

After pressing *Calibrate*, the room calibration is started with five seconds delay.

Move the wand gently within the measurement volume, in order to generate a virtual point cloud. This point cloud should fill at least about two thirds of the measurement volume. Moving the wand in only a very small volume will result in reduced accuracy of calibration.

Therefore, a compromise has to be found between (1) too wide movements that often cause the failing of room calibration, and (2) sparse movements that lead to a valid, but inaccurate room calibration. Avoid rapid and hectic movement (see figure 4.13). During calibration, the two markers of the wand should be visible to both integrated cameras.

After a successful room calibration, the ***DTrack2*** info window with the calibration results is displayed. This window shows the mean residuals for the single cameras (here: '*Residual*' = mean residual of rays during marker detection), as well as the mean deviation

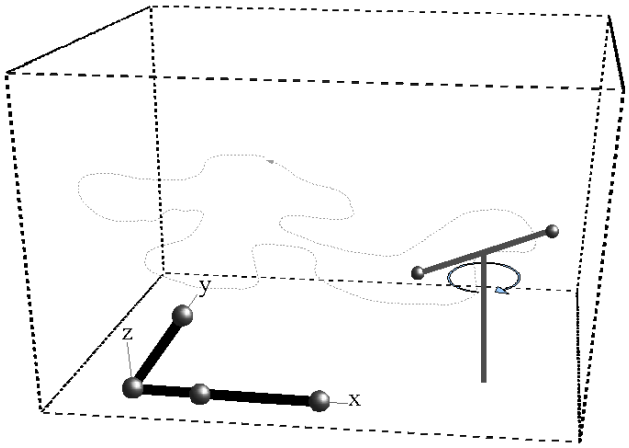


Figure 4.13: Room calibration process

('*wand residual*') and the maximum deviation ('*wand range*') of wand length during the calibration process. These values depend on the system geometry and can give information about the quality of calibration only to an experienced user.

The value '*Used Frames*' represents the percentage of valid (i.e., used for room calibration) data for each camera. It should be as high as possible. Values under 50% indicate poor room calibration quality. The number of valid frames should be greater than 70% for each camera.

The room calibration is confirmed (i.e., the data are stored) by pressing the button *OK*.

Room re-calibration Setups may change after a certain operation time; if e.g. movement due to mechanical instabilities cannot be excluded or thermal drifts occur. In that case it is necessary to perform room calibrations periodically. ***DTrack2*** provides a simplified room calibration to revise an existing room calibration without need of the calibration angle, called room *re-calibration*.

Check the corresponding field in the room calibration dialogue (see figure 4.14) to activate re-calibration. Most settings have to be the same as during the previous standard room calibration, therefore most values of the dialogue cannot be changed - settings regarding the wand may be modified.

The main advantage of a room re-calibration is that ***DTrack2*** preserves the origin of your coordinate system and therefore, the orientation of the coordinate system as well.

4.2.3 Body calibration

The targets for the *SMARTTRACK* are pre-calibrated and, therefore, it is usually not necessary to perform a body calibration.

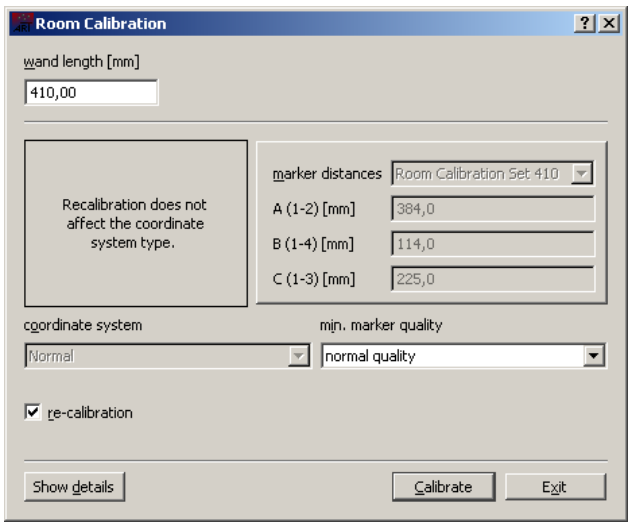


Figure 4.14: Room re-calibration dialogue

However, it will still be possible to perform a body calibration with the ***SMARTTRACK*** in case you want to calibrate self-built targets or if you experience a degradation of tracking performance.

The process of teaching a target's geometry to the tracking system is called body calibration. For a body calibration, the target (= rigid body) to be calibrated has to be in the field of view of both integrated cameras of the ***SMARTTRACK*** . The number of bodies to be tracked has to be configured in *Settings* → *Tracking*.
After pressing *Calibrate*, the body calibration is started within five seconds delay. The body can be moved during body calibration, always considering that the cameras should see each marker of the body at the best.

If the body is not moved during the body calibration it should be considered that each marker of the target has to be seen by the cameras. If two markers, seen from one camera's point of view, are merging to one reflex, body calibration may be affected. These "merging marker situations" should be avoided during body calibration, i.e. the target should be oriented in a way that reduces merging markers to a minimum. The target orientation can be checked before starting the body calibration, using ***DTrack2*** 's Monitor 2DOF display, which is opened automatically in the background after selecting *Calibration* → *Body*.

Furthermore, the absence of any additional markers in the measurement volume has to be ensured for body calibration. If additional markers that are not part of the target to be calibrated are in the field of view of the IR cameras during body calibration, these markers will be assigned to the target. That means, the target is not correctly calibrated and, therefore, tracking problems may occur.

First, the target that shall be calibrated has to be selected in select list *Body*.
The type of body calibration can be set as '*due to body*', '*due to room*' or '*due to room (zero in marker)*'. The difference between these calibration types is to be found in the

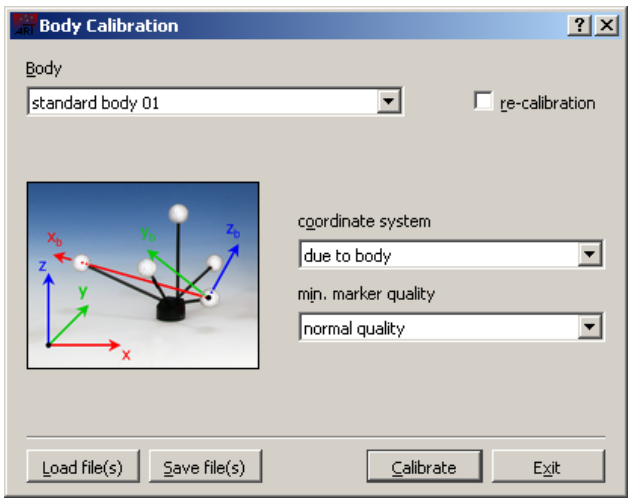
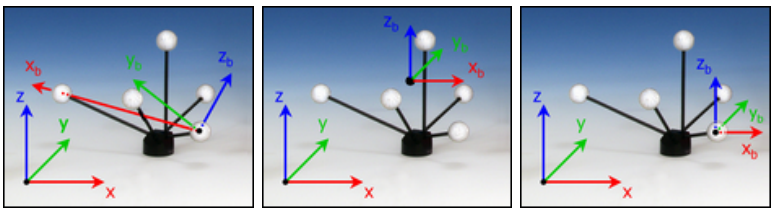


Figure 4.15: Body calibration dialogue

orientation of the body coordinate system relative to the body. During body calibration, ***DTrack2*** defines a local coordinate system (body coordinate system) for each target.

Body calibration setting due to body The body coordinate system is fixed by the markers of the rigid body according to a set of rules:

1. Search the biggest distance between two markers of the rigid body. These two markers (# 1 and # 2) will define the X axis.
2. Search for a third marker (# 3) that has the smallest distance to one of the two markers # 1 and # 2. The marker that has smallest distance to marker # 3 becomes marker # 1. It will define the coordinate origin. The other marker will be # 2. The positive X axis is directed from marker # 1 to marker # 2.
3. Marker # 3 defines the X/Y plane, together with markers # 1 and # 2. Marker # 3 has a positive Y coordinate.
4. The Z axis is already defined by these rules, resulting in a right-handed coordinate system.



(a) Body calibration "due to body"

(b) Body calibration "due to room"

(c) Body calibration "due to room (zero in marker)"

Figure 4.16: Defining the target coordinate system

Body calibration setting due to room The origin of the body coordinate system is set to the center (center of gravity) of all markers building the rigid body. The axes of the body coordinate system are parallel to the axes of the room coordinate system in the beginning of the body calibration. I.e., the result of a body calibration will depend on the angular position of the target during calibration. A 6DOF measurement, following calibration without having moved the body, will give the angular coordinates 0°/ 0°/ 0°.
If the target was moved during calibration, the angular position of the target at the beginning of the calibration will be taken.

Body calibration setting due to room (zero in marker) A combination of the first two methods. The direction of the axes of the body coordinate system will be set parallel to the room coordinate system in the moment of body calibration - like done with setting due to room. The origin of the body coordinate system is given by one marker of the body, according to the rules given for setting due to body.

Within *min. marker quality* you have to select the quality of the recognized markers - default setting is '*normal quality*'. If the quality of the measured markers is worse than the chosen quality, these markers will not be used for the calculation of the body calibration.
The button *Calibrate* activates the body calibration which is starting with a delay of 5 seconds. Body calibration is completed with the presentation of the calibration result.

☞ **Please check if all markers of the rigid body have been recognized.**

Then, confirm the result with *OK*. If this is done, the geometry data of the calibrated target will be stored in the Backend.

After a new room calibration it is not necessary to perform a new body calibration. Only if the body itself changes you have to calibrate the body again.

☞ **The previous body calibration will be lost if you carry out a new body calibration. If you want to save the previous body calibration please use the '*Save file(s)*' option in the *Body calibration* dialogue.**

Calibration with a calibration file The calibration files for our targets are available on request. Each file is specific for just one type of target. It contains the dimensions of the target and the distances between the markers. The file is created at ***ART*** on site performing a body calibration in a defined environment or measurement volume respectively.

Press *Load file(s)* (see figure 4.15) and choose the calibration file(s) for your targets. The format of the file name has to be according to "*standard b01.txt*" - the identifier "*b01*" refers to the ID of the target.

☞ **The previous body calibrations will be lost if you load new calibration files.**

DTrack2 automatically assigns the calibration file to the respective target by using the identifier in the file name.

Invalid or corrupt files are not loaded by *DTrack2* .

This is indicated by an error message in the confirmation dialogue (see figure 4.17). Press '*Load*' to confirm the import of the body calibration files.

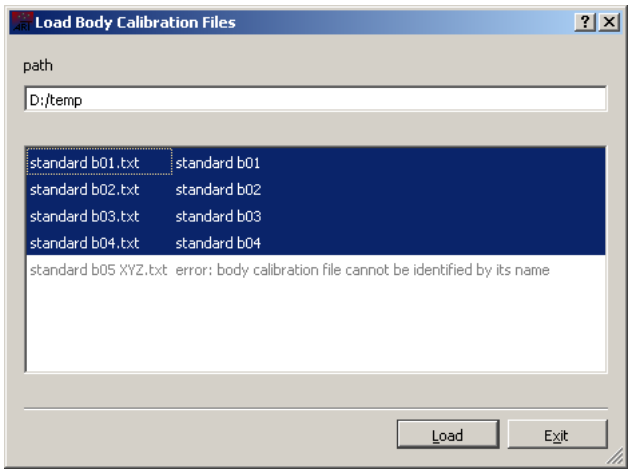


Figure 4.17: Import of calibration files

Press *Save file(s)* to store the body calibration files of the currently used bodies. The files can be saved at a desired location on the remote PC. This function is intended as a simple means for the user to easily create backups of calibrated bodies.

4.2.4 Menu structure

4.2.4.1 Overview

DTrack2	*Shortcut*	page 46
Configurations		Lock the used configuration and save its settings
Start/Stop	M	Start/Stop measurement
ARTtrack Controller standby		Force the ***SMARTTRACK*** to go into standby mode
Quit	Q	Quit ***DTrack2***

Settings	*Shortcut*	page 46
Cameras	F7	Camera settings
Synccard		Synccard settings
A.R.T. Radio Info		Opens a dialogue where you can see available transceivers and devices within your setup
Tracking	F8	General settings for standard ***DTrack2*** targets and options for starting the measurement under special conditions
Output	F9	Set output channels and configure the data to be transmitted
Flystick		Configure your Flystick
Controller		Configure the ATC for your local network

Calibration	*Shortcut*	page 53
Start static reflex scan for all enabled cameras		Starts the static reflex scan
Room	F5	Room calibration
Room adjustment	Shift + F5	Adjust room coordinate system
Body	F6	Body calibration
Body adjustment	Shift + F6	Adjust body coordinate system

Display	*Shortcut*	page 57
Monitor 2DOF		Graphical display of markers recognized by the cameras (monitor 2DOF view)
Data	F10	Display measurement results (6DOF and/or 3DOF)
Flystick		Display Flystick measurement data
Events		Display event messages generated by ***DTrack2***
Set to default		Reset the shown displays to default

About	*Shortcut*	page 58
DTrack2		Frontend software version
ARTtrack Controller		Backend software version
ARTtrack Controller Update		Start the assistant for the ATC update
What's this?	Shift + F1	Help

Table 4.2: ***DTrack2*** menu structure overview

4.2.4.2 Menu DTrack2

DTrack2	*Shortcut*
Configurations	
Start/Stop	M
ARTtrack controller standby	
Quit	Q

Table 4.3: Menu *DTrack2*

Configurations It is possible to protect the used configuration by pressing the button *Lock*. Then, you will be forced to enter a new password and your configuration is locked.

Please do not forget this password! Otherwise, please contact our support.

Log settings saves the active configuration to a text file which can be saved on the remote PC. This function is intended as a simple means for the user to easily create backups of (personalized) configurations.

Start/Stop Start/Stop measurement.

ARTtrack controller standby Force the ***SMARTTRACK*** to go into standby mode with this command. You can restart the ***SMARTTRACK*** by using Wake On LAN. Please refer to chapter 4.1.5 on page 28 for more details.

Quit Quit ***DTrack2*** frontend software - the active measurement doesn't have to be stopped.

4.2.4.3 Menu Settings

Settings	*Shortcut*
Cameras	F7
Synccard	
A.R.T. Radio Info	
Tracking	F8
Output	F9
Flystick	
Controller	

Table 4.4: Menu *Settings*

Cameras This dialogue offers the possibility to adjust the '*flash intensity*' and to activate the '*modulated flash*'. The modulated flash may only be used with active targets. It is used to synchronize an active target.

Reflex suppression *DTrack2* is capable of suppressing reflexes (e.g. sunrays on the floor) in a static way. However, reflex suppression should always be the last option to be considered. If possible try adjusting the cameras in order to minimize reflexes.

You should always be aware that reflex suppression results in removing of the area, in which the reflex originated, from the tracking volume.

There are two possibilities to carry out a reflex suppression:

1. Select *Calibration* → *Start Static Reflex Scan for all enabled cameras* to make sure that static reflexes will be suppressed.
2. While measurement is running you may define the areas to be suppressed manually. In the Monitor 2DOF display, right-click on the respective camera window and enable '*Edit reflex suppression areas*'. Alternatively, you may use the shortcut ('*E*') to enable this mode (shown in figure 4.18(a) on page 48).

   Within the edit mode you may (also refer to figure 4.18(b) on page 48)
   - create new areas,
   - delete areas,
   - clear regions,
   - resize areas and
   - move areas.

   Reflex suppression areas are enabled when you leave the edit mode (by disabling '*Edit reflex suppression areas*') and accept the changes. The single areas defined are stored in the ***SMARTTRACK*** and can be edited each time you enter this mode.

Flash settings The flash intensity may be changed within an interval of 0 .. 7.
These settings strongly depend on the working area and range. If you have a small working area where you are close to the cameras small flash intensities may be sufficient. Otherwise, if your working area is a bit further away from the ***SMARTTRACK*** (but still within tracking range) it may be necessary to change to greater flash intensities.

Generally speaking, you should adjust the flash settings in a way that the recognized markers are coloured in green or yellow.

Do not look directly into the camera from short distance for a longer period of time!
Please refer to chapter B on page 76 for more information.

(a) Reflex suppression edit mode

(b) Reflex suppression edit mode help

To be safe, always double-check whether the markers of the target are seen properly by the cameras. Therefore, please use the Monitor 2DOF view:

- markers coloured in red are characterized by bad circularity, small size or low intensity; this may result in poor tracking quality
- markers coloured in yellow offer a good tracking quality
- markers coloured in green offer a very good tracking quality

Increase the flash intensity until all markers are yellow or green (recommended).

Synccard This dialogue shows the model and the serial number of the synccard. Furthermore, it offers a dropdown list to select the mode of synchronization.
Basically, you can select between internal and external synchronization. The further differentiation is shown in table 4.5.

supported synccard mode	field of application
internal generated signal (15 - 60Hz)	
external video signal external video signal, for validated shutter glasses [1] external video signal, for validated shutter glasses, divisor 2 [2]	active-stereo projection with an analogue video sync signal (=VGA)
external TTL signal external TTL signal, for validated shutter glasses [1] external TTL signal, for validated shutter glasses, divisor 2 [2]	active-stereo projection with a TTL sync signal
direct settings	advanced custom settings

[1] predefined settings that should be used with the shutter glasses mentioned in table 4.6
[2] if, additionally, the frequency of the external synchronization signal is greater than 60Hz, this mode should be used

Table 4.5: Overview of the supported synccard modes

If you select '*direct settings*' you may use advanced options for configuring the synccard:

Option	Description
source	configure the type of synchronization to be '*internal*', '*video*', '*ttl*' or '*ttlinv*'
frequency [Hz]	change the frequency in an interval of 10 Hz to 60 Hz (only for internal synchronization!)
divisor for external signal	reduce the tracking frequency (only for external synchronization!)
Delay [us]	configure the delay between the syncgroups

Brand	Type
RealD	CrystalEyes 1, 2, 3, 5
NuVision	APG6000, APG6100
XPand	X103 (with NuVision Long-Range Emitter)
NVidia	3D Vision Pro (RF sync'ed)
Volfoni	EDGE (with Volfoni or NuVision LR Emitter)

Table 4.6: Overview of validated shutter glasses

A.R.T. Radio Info When you are using a Flystick, for example, you will get information about the used transceiver and the Flystick device itself. The following information is offered:

	Description
'*Model*'	the model of the transceiver or the device respectively
'*Serial*'	the serial number
'*Version*'	the firmware version
'*Is free (only for Devices)*'	the device is not free (= '*no*') if it is assigned to an interaction device ID
'*Is present*'	the device or the transceiver is present in the tracking volume

By clicking the button *Show details* you may change the channel the transceiver is transmitting on.

Tracking The *number of 6DOF bodies* represents the number of targets that should be tracked. In this context, the number of targets does not include the interaction devices (e.g. Flystick2, Flystick3). These are completely configurable in separate menus.

However, the maximum total number of bodies that may be used with the *SMARTTRACK* includes the calibrated interaction devices (i.e. Flystick)!

The two checkboxes which allow more sophisticated settings are described in table 4.7).

Checkbox	Description
'*calculation of 3DOF markers*'	Calculate the coordinates of single markers.
'*automatic start of measurement after booting*'	The measurement is started directly after booting the ATC or ATC/TP.
'*automatic restart of measurement after loss of sync signal*' [1]	As soon as ***DTrack2*** acquires the sync signal again the measurement is started.

[1] has been used formerly. Now, activated by default and not changeable.

Table 4.7: Tracking settings - Description of the checkboxes

Advanced In the *Advanced* menu ***DTrack2*** presents an overview of the number of bodies you have configured before. The name and state ('*calibrated*' or '*not calibrated*') of each body is shown. By default, the name is left blank. You are free to define a name for each body. Just double-click into the name field and enter a name for the specific body. The entered name will appear in the data display as soon as you start the measurement.

Output The dialogue *Output* determines the settings of data output via Ethernet. Data output will be enabled when you tick the checkbox *active*.

In total, up to 5 UDP channels for ***DTrack2*** data output can be configured. Tick the checkbox *this computer* to send data to the remote PC you are currently working at. If you want to send data to any computer within your local network just enter the IP address of the receiver and a port number. In addition, it is possible to define a *multicast* output. By ticking this checkbox the UDP data is sent to a group of addresses in the range of 225.0.0.0 to 238.255.255.255.

In order to reduce the data of the UDP output data stream you may set the '*send data divisor*' to values from 1 to 10. The numbers have the following meaning:

- 1 .. every frame is transmitted,
- 2 .. every second frame is transmitted,
- ...

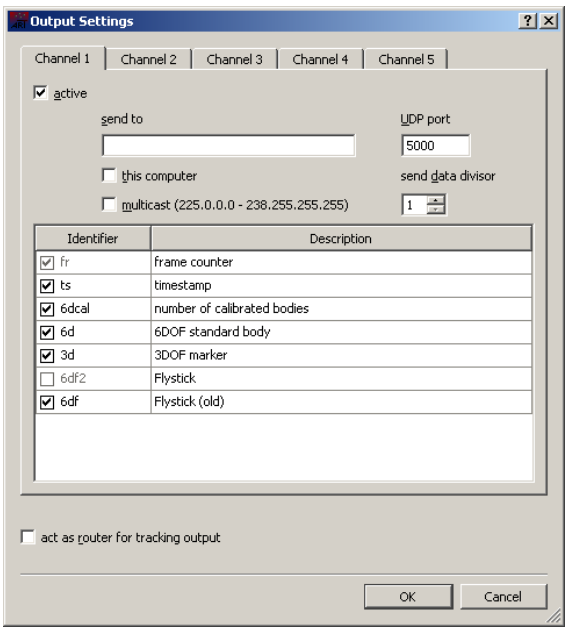


Figure 4.18: Output settings

Identifier	Description
fr	frame counter
ts	timestamp
6dcal	number of calibrated bodies
6d	6DOF standard body
3d	3DOF marker
6df2	Flystick
6df	Flystick (old) only available if activated in Flystick settings (→ checkbox '*use old output format*')

Table 4.8: Output identifiers

- 10 .. every tenth frame is transmitted.

The UDP output data may be routed by ***DTrack2*** by ticking the checkbox *act as router for tracking output*. This functionality is especially important for customers where it is not allowed to connect the ***SMARTTRACK*** to their local network due to security reasons.

The mandatory requirement to use this function is that the PC, where ***DTrack2*** is installed, needs to have two separate Ethernet plugs: one for connecting to the ***SMARTTRACK*** and one for the respective local network. The ***DTrack2*** frontend reads the data from the ***SMARTTRACK*** and routes it to the local network where the application PC is connected to.

Using this function will cause a short delay during forwarding of the data.

Do not use this function if the application PC and the ATC are in the same network!

Please refer to chapter C on page 79 for the format of the data output.

Flystick In the *Flystick Settings* you can define the *number of Flysticks* to be used.

Checkbox	Description
'*use old output format*'	Use the output format of the old Flystick1 (see chapter C on page 79)

Table 4.9: Flystick settings - Description of the checkboxes

Below, there are two more properties which can be configured for Flystick3:

- *sync groups*:
  Configure your Flystick3 to send out IR flashes for one or more syncgroups (syncgroup #1, syncgroups #1 and #2, . . . ; default = syncgroup #1).
- *flash intensity*:
  Set the flash intensity of the active target of the Flystick3 (default = 3) by moving the slider.

If you change the number of Flysticks you will immediately recognize entries in the *selected Flysticks* field. The fields *Model*, *Serial* and *Port* are empty by default.
Make sure that your Flystick is in the *available Flysticks* list - if necessary, compare the serial number listed here to the one printed on the battery compartment of the Flystick2 or on the back cover of the Flystick3. Now, you have to assign your Flystick to the respective Flystick ID.

Therefore,

- mark the respective Flystick ID,
- mark the desired available Flystick and
- press *Select*.

Repeat these steps if you want to use another Flystick. Please refer to chapter 5.1 on page 60 to learn how to install the Flystick2 and refer to chapter 5.2 on page 65 for the Flystick3.

Controller The menu for the *Advanced ARTtrack Controller Settings* is divided into two tabs - *Network* and *Time*.
On the *Network* tab you may change the *hostname* (not recommended!) and the *domain* according to your network guidelines. When the network cable has been plugged into the ***SMARTTRACK*** while booting, the ***SMARTTRACK*** is a DHCP client and the checkbox is ticked. If the network cable is unplugged while booting the ***SMARTTRACK*** uses its default IP address (i.e. 192.168.0.1).
You may also specify *IP address*, *subnet mask*, *gateway* and *nameserver* as desired. The MAC address of the ***SMARTTRACK*** is printed in the last line for your information (*ethernet-MAC LAN*).

On the *Time* tab you can set the *UTC time* of the ***SMARTTRACK*** . Furthermore, you can synchronize the UTC (=Universal Time Coordinated) time using NTP (=Network Time Protocol). NTP is a protocol designed to synchronize the clocks of computers over a network. Tick the checkbox *activate NTP* and enter hostname or IP address of your server.
If NTP is activated the ***SMARTTRACK*** is trying to connect to the NTP server repeatedly in order to update its clock. The values for '*reachability*' range between 0% - 100% (typically). They are a measure for the quality of the reachability of the NTP server. Only NTP servers which are contacted over the internet may provoke some problems. The quality of the synchronization of the clocks is indicated with '*estimitated precision*' in the

unit milliseconds (=ms).

Synchronizing with NTP takes quite a long time. Active measurements won't be disturbed.

4.2.4.4 Menu Calibration

Calibration	*Shortcut*
Start static reflex scan for all enabled cameras	
Room	F5
Room adjustment	Shift + F5
Body	F6
Body adjustment	Shift + F6

Table 4.10: Menu *Calibration*

Start static reflex scan for all enabled cameras Scanning for static reflexes allows searching the measurement volume for unwanted reflexes. Areas are defined around the visible reflexes, where all reflexes should be suppressed later during measurements.

Be sure to remove all targets from the measurement volume before starting the scan.

Room Use the room calibration menu to configure your room calibration set concerning *wand length* and *marker distances*. The wand length is printed on a label on the wand - please enter the value here.

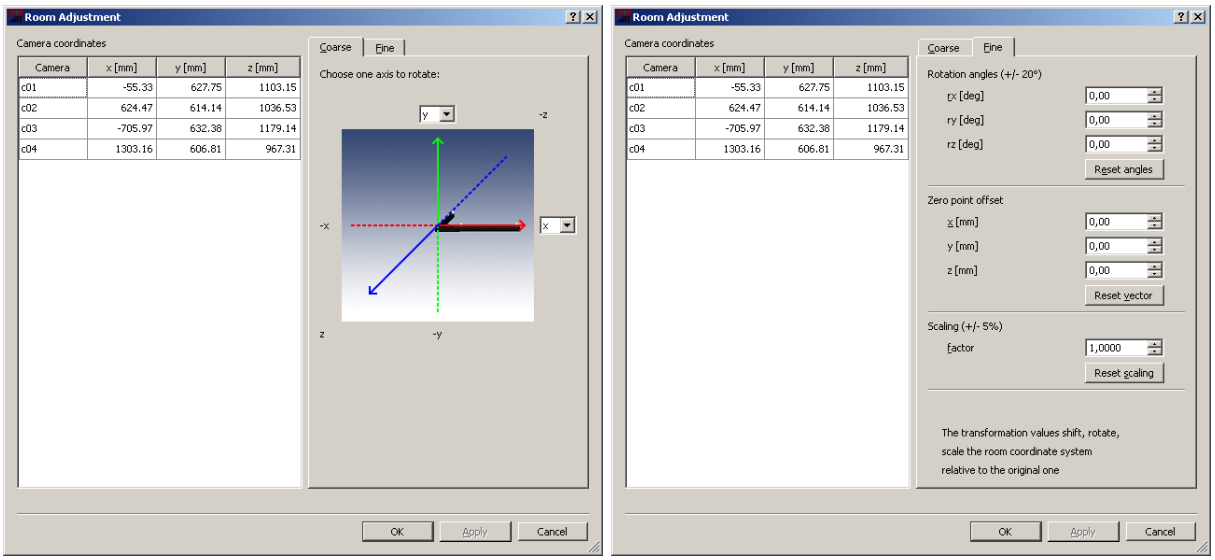
Figure 4.19: A room calibration set consisting of angle and wand

If you are re-calibrating your room use the checkbox *re-calibration* in the bottom left corner to indicate it to the tracking system. For more information about room re-calibration

please refer to page 40.

Please refer to chapter 4.2.2 on page 37 for the details on how to perform a room calibration.

Room adjustment In many cases it might be necessary to shift or rotate the default coordinate system after calibration. The functionality is called from *Calibration* → *Room adjustment*.



(a) '*normal*' (b) '*powerwall*'

Figure 4.20: Room adjustment dialogue

Coarse The *Coarse* menu offers the opportunity to manipulate the orientation of the room coordinate system with just one click. You can define the orientation of two axes - the third one will be oriented automatically according to the right-hand rule.

Fine The offsets in this menu are the coordinates of the new (desired) coordinate system in the original coordinate system ('*Middle of cameras*'). Angular corrections are only allowed up to 20° in any direction. The transformation values shift, rotate and scale the room coordinate system relative to the original one.

Body Select the body you want to calibrate and tick the checkbox if you want to perform a re-calibration. Define the coordinate system which can be '*due to body*', '*due to room*' or '*due to room, zero in marker*'.

Type of coordinate system	Description
'*due to body*'	the body coordinate system is completely defined by the target geometry
'*due to room*'	the body coordinate system is oriented parallel to the room coordinate system. In these cases, the orientation of the body during body calibration defines the orientation of the body coordinate system relative to the body. If the body is moved, the orientation of start position is used.
'*due to room, zero in marker*'	

The recommended value for the marker quality is '*normal quality*'. If you want to use body calibration files for calibrating your target, just click *Load file(s)* and select the appropriate calibration file(s). By clicking on *Save file(s)* you can save your body calibrations in separate text files.

Please refer to chapter 4.2.3 on page 40 for the details on how to perform a body calibration.

Body adjustment If you want to manipulate calibration data of rigid bodies this menu offers the solution. Just select the body you want to manipulate from the drop-down list which appears at the top of the window. Then, you have the choice between a *general* or a *special* manipulation:

General manipulation The body coordinate system may be defined in a general manner, i.e. as desired by the user.

Action	Description
Body position [mm]	translate the body coordinate system along its axes in steps of 1mm
Body orientation [deg]	rotate the body coordinate system around its axes
Set origin	activate a marker in the graphic view by left-clicking with the mouse. The marker is highlighted and the button *Set origin* is activated. Pressing this button translates the origin of the body coordinate system into the center of the selected marker.
Set origin to COG	translate the origin of the body coordinate system into the target's center of gravity
Set axis	activate two markers sequentially in the graphic view by left-clicking with the mouse. The first one is highlighted in white, the second one in grey. Additionally, the button *Set axis* is activated. Pressing this button opens a dialogue to configure the transformation.
Adjust axes to room	pressing this button aligns the body coordinate system in parallel to the room coordinate system

Special manipulation Choose from the following predefined transformations:

- *due to body*
  The body coordinate system is completely defined by the target geometry (see page 42).
- *due to room (origin in COG)*

The coordinate system is rotated in order to be aligned in parallel to the room coordinate system with the origin to be in the center of gravity (COG) (see page 43). In order to use this function, the checkbox '*use tracked orientation*' has to be ticked.

- *due to room (origin in marker)*
  The coordinate system is rotated in order to be aligned in parallel to the room coordinate system with the origin to be in the marker (see page 43). In order to use this function, the checkbox '*use tracked orientation*' has to be ticked.

The default view for the calibration data of the rigid body is the '*Graphic view*'. Press the right mouse button and a menu with the following options pops up:

Option	Description
'*Small markers*'	reduce the size of the markers
'*Colored markers*'	show the markers in different colours (default: greyish)
'*Long axes*'	extend the vector arrows of the body coordinate system by infinite dashed lines
'*Show COG*'	show the center of gravity when changing the orientation of the view
'*Show XY plane*'	show the XY plane
'*Show YZ plane*'	show the YZ plane
'*Show XZ plane*'	show the XZ plane
'*Show room orientation*'	shows the room coordinate system (only available when checkbox '*use tracked orientation*' is ticked)
'*Add line between markers*'	add a line between two selected markers (option greyed out until two markers are selected)
'*Delete line between markers*'	remove a line between two selected markers (option greyed out until line is selected)
'*Data view*'	switch to the data view

The *View position* and *View orientation* may be changed according to the customer's choice. The graphic view may be moved along and/or rotated around the axes. This may be achieved in two different ways:

1. hold down the "Strg" key and the left (right) mouse button to change the position (orientation)
2. use the six control dials to adjust position and orientation

To restore the default view, just press '*Reset view*'. Tick the '*use tracked orientation*' checkbox if you want to rotate or move the target in the graphic view by rotating or moving the real target within the measurement volume.

If you press *OK*, the changes which have been done for all bodies will be confirmed (changes are sent to the controller) and the dialogue closes.
Pressing *Apply* only results in a confirmation of the changes only for the currently selected body - the body will directly be reloaded afterwards.

4.2.4.5 Menu Display

Display	*Shortcut*
Monitor 2DOF *Data* *Flystick* *Events*	F10

Table 4.11: Menu *Display*

Monitor 2DOF The *Monitor 2DOF display* essentially is a graphical display of the field of view of the ***SMARTTRACK*** and of the markers that are seen by it. The Monitor 2DOF display shows two black windows (equivalent to the field of view), with a schematic display of positions and sizes of all recognized markers. A simple color code signifies the size and the circularity of the markers (green = very good quality, yellow = good quality, red = poor quality).
Each marker is either displayed as a circle or as a cross. This indicates the projected size of the marker on the CCD chip inside the camera (i.e. circle = big marker and cross = small marker).

In the *Monitor 2DOF display* it is possible to interact with your mouse as certain functions are assigned to the mouse buttons.

- left mouse button:
  Click and hold down to move a camera display within the *Monitor 2DOF view*.
- middle mouse button:
  Click to hide all camera displays except for the one you pointed at. Click once again and all camera displays are shown.
- right mouse button:
  A menu is opened; see table 4.12 for more details.

Data On the left hand side, the *Data* display shows the 6DOF measurement results of the position and orientation of the body relative to the room coordinate system. The rotation angles are rotations around the X, Y and Z axis. The mathematical definition can be found in chapter C on page 79. A simple colour code indicates if the body is tracked or not:

green	...	body is being tracked; tracking data is displayed
red	...	body is not being tracked; instead of tracking data dashes are displayed
white	...	body is not calibrated; columns are left blank

On the right hand side, the 3DOF calculation for single markers or uncalibrated targets is shown. All recognized single markers that are have not been assigned to a calibrated

Function	*Shortcut*	
Grid	G	Shows a grid in the camera display.
Cross	C	Shows a cross in the camera display.
Fullscreen	F	Resizes *Monitor 2DOF view* to full screen and back.
One Camera		Only show the view of the selected camera.
Static Reflex Suppression		
Start scan for all enabled cameras		Initiates a scan for static reflexes. Enabled only if *Active* is ticked.
Edit reflex suppression areas	E	Enter the reflex suppression area edit mode in order to interactively suppress unwanted reflexes.

Table 4.12: Features of the *Monitor 2DOF view*

6DOF body are shown here.
Note that the *calculation of 3DOF markers* has to be activated in *Settings* → *Tracking* by ticking the checkbox. Otherwise, the positions will not be calculated.

Flystick The *Flystick* display shows the measurement results of the position and orientation of the Flystick. Additionally, the operation of the Flystick buttons and of the joystick are shown. A simple colour code shows the status of the Flystick:

green	...	Flystick is being tracked; tracking data is displayed
red	...	Flystick is not being tracked; instead of tracking data dashes are displayed
blue	...	button is being pressed
white	...	Flystick is not calibrated; columns are left blank

Events The *Event display* presents the status of the tracking system. It offers feedback of the operational state concerning errors or warnings. Furthermore, it informs the user about successful room or body calibrations. Each entry is associated with a timestamp and date.

Set to default If, for some reason, the appearance of the ***DTrack2*** Frontend got messed up you may reset all views and the size of the window back to default values. This means that only the *Monitor 2DOF*, the *Data* and the *Events* displays are shown (refer to figure 4.7 on page 35).

4.2.4.6 Menu About

DTrack2 Offers information about the software version and release date of the ***DTrack2*** frontend software. By clicking on the button *Show details* you receive a list of every single software module with the respective software version.

About	Shortcut
DTrack2	
ARTtrack Controller	
ARTtrack Controller Update	
What's this?	Shift + F1

Table 4.13: Menu *About*

ARTtrack Controller Offers information about the software version and release date of the ***DTrack2*** backend software. Additionally, name and serial number of the ***SMARTTRACK*** are shown.

ARTtrack Controller Update If you update your ***DTrack2*** frontend software it is mandatory that you also update the software of the ***SMARTTRACK*** . An assistant will guide you through the process of the software update. In case you abort the update of the ***SMARTTRACK*** software (not recommended!) during this process you can carry it out later. Just click *About* → *ARTtrack Controller update* and follow the instructions of the assistant given during this process.
Please restart the ***SMARTTRACK*** after the assistant finished.

Personal settings and configurations (e.g. room and body calibration, output settings, etc.) will not be lost during update!

What's this? By clicking *What's this*, you may use our context-sensitive help function within ***DTrack2*** frontend software. Just use the mouse cursor to point on any feature of the ***DTrack2*** GUI and you will receive an information with a click on the left mouse button.

5 Interaction devices

5.1 Flystick2

The batteries must be removed before shipping the Flystick2, otherwise the radio transmitter could be started by shock or vibration.

Description The Flystick2 is a wireless input device for ***ART*** infrared optical tracking systems.

Figure 5.1: Flystick2

The Flystick2 has a trigger, four buttons and an analogue joystick with an additional button functionality. All interactions are transmitted wirelessly via a 2.4 GHz ISM radio connection. The software ***DTrack2*** takes up the Flystick2 button & joystick events and correlates them with the 6DOF output data. Tracking and interaction data are then transmitted to the application via Ethernet.

The Flystick2 has no power switch. It is activated automatically within a few seconds after any button event and is deactivated after several minutes without usage.
The Flystick2 is tracked via passive markers which are covered by an acrylic housing. This means that 6DOF tracking is still valid when the Flystick2 electronics is off.

Top view		
status LEDs	green pulse	→ button pressed or joystick position successfully transmitted
	yellow pulse	→ button pressed or joystick position could not be transmitted
	yellow flashing	→ low battery, recharge soon
trigger, button and joystick	press the trigger or any button to invoke an interaction which can be defined in the user application (e.g. drag objects while button trigger pressed, open a menu dialogue, . . .)	

Table 5.1: Description of the Flystick2

The output data consists of:

- position and orientation of the Flystick,
- status of buttons and joystick,
- number of used Flysticks.

Please refer to chapter C for more information about the format of the output data.

Control elements The numbering sequence of the buttons is as follows:

- # 1 trigger
- # 2 - # 4 blue buttons, right to left
- # 5 pressing the joystick

Figure 5.2: Flystick2 control elements

In neutral position the joystick transmits x=0, y=0.

- Moving left creates negative x values, moving right positive x values.
- Moving down creates negative y values, moving up positive y values.
- Full extension into any direction creates values of 1.0 or -1.0.

The Flystick2 device provides all functions (buttons, trigger and joystick) simultaneously.

Radio module The Flystick2 uses a radio module in the 2.4GHz band. This band is standardized internationally and can be used without a license. Range with line of sight is more than 7m but can be reduced when passing material, e.g. projection screens.

Radio Transceiver2 The USB Radio Transceiver2 has to be plugged in to any free USB port of the controller before the controller is switched on. During operation, please do not unplug the USB radio transceiver. This would lead to malfunction of the tracking system.

Please make sure that either the old radio transceiver (connected via the camera network) or the new USB radio transceiver RT2 is connected to the controller. Connecting both radio transceivers to one controller would lead to malfunction of the Flystick2 or Flystick3.

Switch on the controller. LED (2) which is framed by a circle (see figure 5.3) lights continuously while controller is booting. When ***DTrack2*** is started, LED (1) which is framed by a square (see figure 5.3) is switched on and indicates that the radio transceiver was correctly initialized; LED (2) extinguishes.
During measurement, LED (1) is flashing whenever data is received from or transmitted to the Flystick. In case of unsuccessful data transmission to the Flystick, LED (2) starts flashing.

Figure 5.3: USB Radio Transceiver2

Battery pack The battery compartment is at the lower end of the handle. It is fixed with a single screw which can be opened with the supplied 2mm hexagon key. Remove the screw and take off the cover of the battery compartment.
Insert the battery pack taking care of the polarity - also note the imprinting "<<INSERT<<" on the battery pack. Apply the cover of the battery compartment again and fix the screw.

(a) Step 1 (b) Step 2 (c) Step 3

Figure 5.4: Flystick2 - inserting the battery pack

The battery pack includes 3 standard AAA rechargeable batteries.

The polarity of the batteries is indicated inside the battery pack. The rechargeable batteries must be inserted into the battery pack in the indicated polarity.
Dispose used batteries according to governmental regulations (life cycle approximately 2 years).

Risk of explosion if battery is replaced by an incorrect type!

Charging jack The charging jack is at the bottom of the handle and has to be connected with the supplied battery charger.

Figure 5.5: Charging the battery of the Flystick2

To prevent damage the battery charger automatically disconnects the Flystick2 electronics. That is why using the Flystick2 with connected charger is not possible.

The rechargeable batteries may only be charged with the supplied charger. To ensure a long life cycle, only recharge the batteries if they're empty.

Battery charger A battery charger is supplied with the delivered Flystick2 and must be used for charging the batteries. For your convenience, the battery pack may remain inside the Flystick2 for charging. However, during the charging process the Flystick2 cannot be used.

As soon as the battery pack is connected to the charger, the red LED ("Charge") is switched on and the green LED ("Ready") starts flashing - the testing cycle is started. After approximately 1min the testing cycle is over (the green LED extinguishes) and the charging process starts.

Once the battery pack is fully charged the charger switches off the "Charge" LED, the "Ready" LED is switched on and the charger goes into trickle charging mode automatically (indicated by a flashing "Ready" LED). Now, the battery pack may be used again.

Please also refer to table 5.2 for an overview of the status LEDs on the battery charger.

Status LED	Colour	Description
Power	red	is switched as soon as the charger is connected to the power plug
Charge	red	is switched on while the charging process is active
Ready	green	is switched on for approx. 2min when the battery pack is fully charged and starts flashing afterwards is flashing during the testing cycle
Discharge	yellow	is switched on when the discharging process has been initialised by pressing the yellow button
Button for discharging	yellow	starts the discharging process

Table 5.2: Status LEDs quick reference

If you want to discharge the battery pack prior to charging, just press the yellow button for about 2sec to initiate the discharging process ("Discharge" LED is switched on). This may take several hours in some cases. However, after this procedure, the battery charger automatically switches over to the charging process.

Body calibration First, configure the number of Flystick2 you are using: select *Settings* → *Flystick* and configure the *number of Flysticks*. You have to assign your Flystick2 to a '*Flystick ID*' by selecting, for example, '*F1*' and selecting your Flystick2 out of the '*available Flysticks*' list.
Now, press *Select* to finalize the assignment.

If the '*available Flysticks*' list doesn't contain your Flystick2 although it is already present, just press any button of the Flystick2 to register it at the radio transceiver.

Then, select *Calibration* → *Body calibration*.
In the appearing dialogue the body to be selected is named '*Flystick body 01*'. Please define the orientation of the body coordinate system relative to the body (default setting is '*due to body*'). Make sure that all markers of the Flystick2 are seen by the cameras using the *Monitor 2DOF display* which appears in the background.

Press *Calibrate* and the calibration starts within 5 seconds. Please refer to page 40 for more information concerning *body calibration*.

Output settings Please define where the Flystick data has to be sent to. In ***DTrack2*** frontend software, select *Settings* → *Output*. You can either select *this computer* (= remote PC) or enter an IP address of another computer you want to send data to. By ticking the checkbox '*6df2*' you can define the Flystick data to be transmitted.
Please refer to chapter 4.2.4.3 on page 50 for more details.

Press *Start* to start the measurement. In order to see the tracking data you have to enable the Flystick display by clicking *Display* → *Flystick*.

5.2 Flystick3

The batteries must be removed before shipping the Flystick3, otherwise the radio transmitter could be started by shock or vibration.

Description The Flystick3 is a lightweight input device for ***ART*** infrared optical tracking systems.

(a) active target (b) passive target

Figure 5.6: Flystick3

Top view		
status LEDs	green pulse	→ button pressed or joystick position successfully transmitted
	yellow pulse	→ button pressed or joystick position could not be transmitted
	yellow flashing	→ low battery, recharge soon
trigger, button and joystick	press the trigger or any button to invoke an interaction which can be defined in the user application (e.g. drag objects while button trigger pressed, open a menu dialogue, . . .)	

Table 5.3: Description of the Flystick3

It is equipped with an active[1] or passive target, a trigger, three buttons and an analogue joystick for wireless interaction in a virtual environment. Like with the Flystick2, all interactions are transmitted wirelessly via a 2.4 GHz ISM radio connection. Synchronization of the Flystick3 is provided wirelessly with a modulated flash by one camera.

The software ***DTrack2*** takes up the Flystick3 button and joystick events and correlates them with the 6DOF output data. Tracking and interaction data are then transmitted to the application via Ethernet.

The radio transmission and the active target are switched off after 15 minutes without usage. Press any button to reactivate the Flystick3 and, therefore, tracking.

The output data consists of:

- position and orientation of the Flystick,
- status of buttons and joystick,
- number of used Flysticks.

Please refer to chapter C on page 79 for more information about the format of the output data.

Control elements The numbering sequence of the buttons is as follows:

- # 1 trigger
- # 2 - # 4 blue buttons, right to left

In neutral position the joystick transmits x=0, y=0.

- Moving left creates negative x values, moving right positive x values.
- Moving down creates negative y values, moving up positive y values.
- Full extension into any direction creates values of 1.0 or -1.0.

The Flystick3 device provides all functions (buttons, trigger and joystick) simultaneously.

[1] discontinued in December 2011

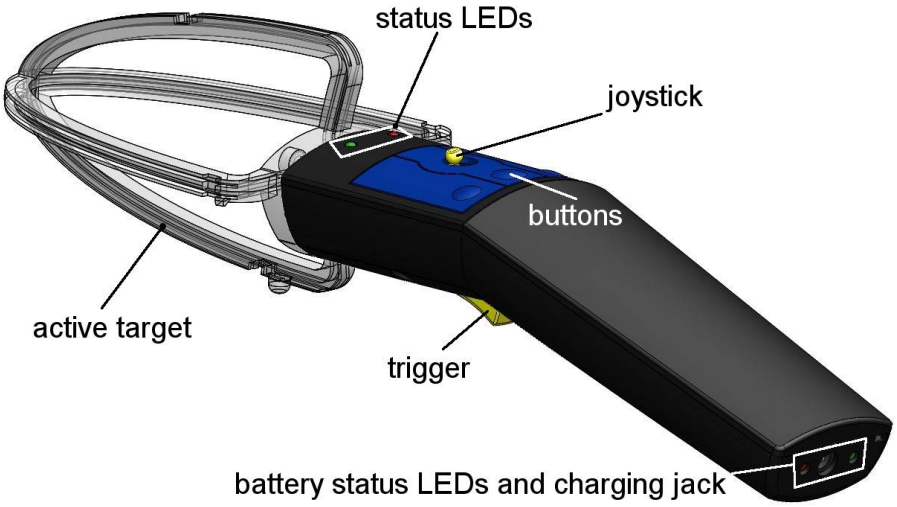


Figure 5.7: Flystick3 control elements

Radio Transceiver2 The USB Radio Transceiver2 has to be plugged into any free USB port of the *SMARTTRACK* before it is switched on. During operation, please do not unplug the USB radio transceiver. This would lead to malfunction of the tracking system.

Please make sure that either the old radio transceiver (connected via the camera network) or the new USB radio transceiver RT2 is connected to the *SMARTTRACK* . Connecting both radio transceivers to one *SMARTTRACK* would lead to malfunction of the Flystick2 or Flystick3.

Switch on the *SMARTTRACK* . LED (2) which is framed by a circle (see figure 5.3) lights continuously while the *SMARTTRACK* is booting. When *DTrack2* is started, LED (1) which is framed by a square (see figure 5.3) is switched on and indicates that the radio transceiver was correctly initialized; LED (2) extinguishes.
During measurement, LED (1) is flashing whenever data is received from or transmitted to the Flystick. In case of unsuccessful data transmission to the Flystick, LED (2) starts flashing.

Battery charger A battery charger is supplied with the delivered Flystick3 and must be used for charging the batteries. For your convenience, the battery pack may remain inside the Flystick3 for charging. During the charging process you may continue using your Flystick3.

As soon as the battery pack is connected to the charger, the red LED ("Charge") is switched on. Once the battery pack is fully charged the charger switches off the "Charge" LED, the green "Ready" LED is switched on. Now, the battery pack may be used again.

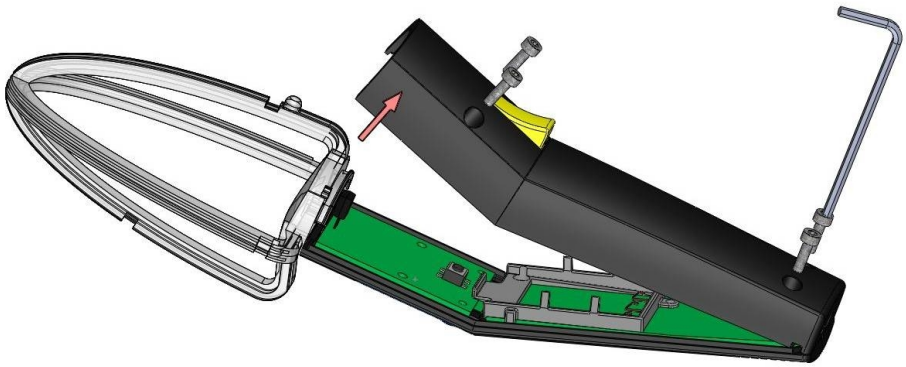
The rechargeable batteries may only be charged with the supplied charger.

Inserting the battery For inserting the battery into the Flystick3, you have to take off the back cover completely.

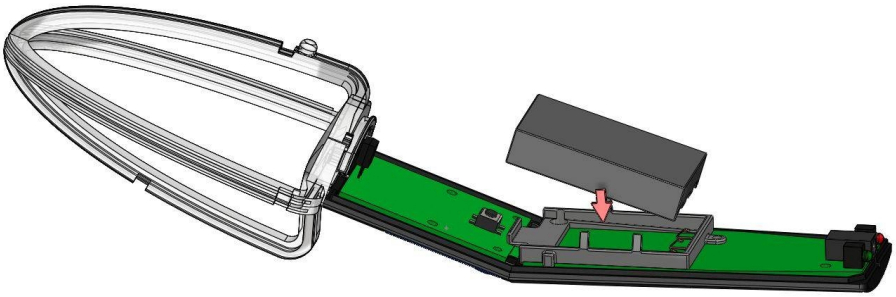
Risk of explosion if battery is replaced by an incorrect type!

Dispose used batteries according to governmental regulations.

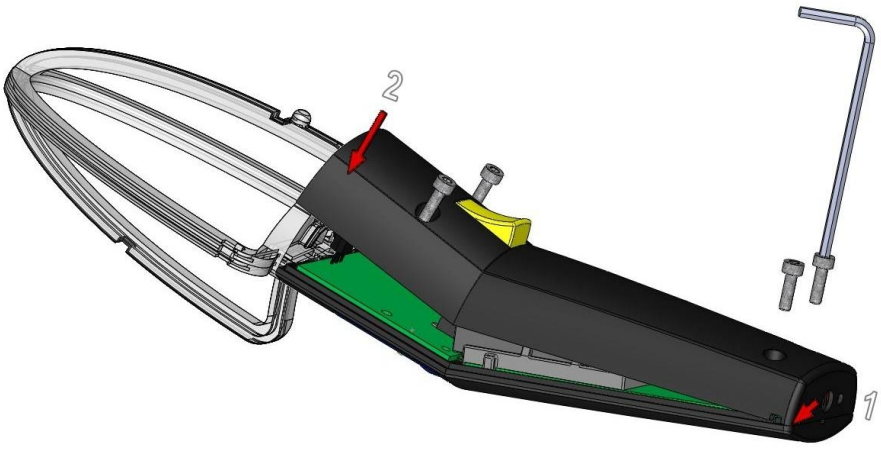
Therefore, loosen the four screws using the 2.5mm hexagon key and remove the back cover.



Place the battery correctly within the cut-out.



Apply the back cover again and tighten the screws carefully.



Wireless synchronization The receiver for the modulated infrared signal which is used for synchronization is located in the middle of the joint between transparent target and handpiece (see figure 5.8).

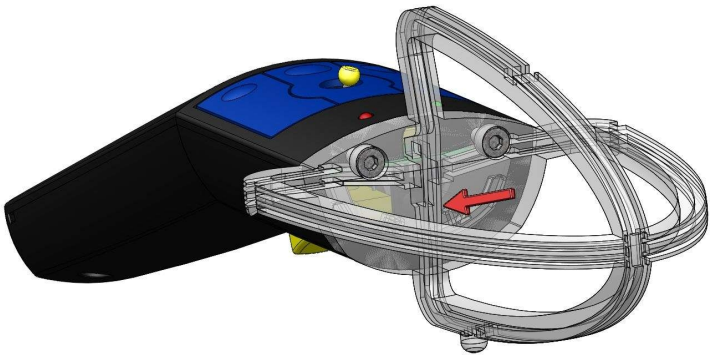


Figure 5.8: Position of the receiver for synchronization

Active targets need synchronization in order to make sure that the IR LEDs are flashing at the proper time. To ensure wireless synchronization the following points should be observed:

- **Note that the synchronization will not work near plasma screens.**
- **If two or more tracking systems using wireless synchronization are in the same room, then external synchronization of the systems might be necessary (e.g. at tradeshows).**

Body calibration First, configure the number of Flystick3 you are using: select *Settings* → *Flystick* and configure the *number of Flysticks*. You have to assign your Flystick3 to a '*Flystick ID*' by selecting, for example, '*F1*' and selecting your Flystick3 out of the '*available Flysticks*' list.
Now, press *Select* to finalize the assignment.

If the '*available Flysticks*' list doesn't contain your Flystick3 although it is already present, just press any button of the Flystick3 to register it at the radio transceiver.

Then, select *Calibration* → *Body calibration*.
In the appearing dialogue the body to be selected is named '*Flystick body 01*'. Please define the orientation of the body coordinate system relative to the body (default setting is '*due to body*'). Make sure that all markers of the Flystick3 are seen by the cameras using the *Monitor 2DOF display* which appears in the background.

Press *Calibrate* and the calibration starts within 5 seconds. Please refer to page 40 for more information concerning *body calibration*.

Output settings Please define where the Flystick data has to be sent to. In ***DTrack2*** frontend software, select *Settings* → *Output*. You can either select *this computer* (= remote PC) or enter an IP address of another computer you want to send data to. By ticking the checkbox '*6df2*' you can define the Flystick data to be transmitted.
Please refer to chapter 4.2.4.3 on page 50 for more details.

Press *Start* to start the measurement. In order to see the tracking data you have to enable the Flystick display by clicking *Display* → *Flystick*.

6 General Information

6.1 Service

It is recommended to maintain the equipment every three years. If you experience any problems please do not hesitate to contact our support.

Never try to repair anything yourself!!

Opening the equipment implies risks for health and environment as well as loss of warranty and liability.

6.2 Cleaning of the equipment

Only the housing of the cameras may be cleaned. Before cleaning shut down the system and disconnect the power cords.
Never use water or any chemicals. Just use a dry, lint-free and antistatic tissue like lens-cleaners for optical equipment.

Do not open the housings!

Opening the housings implies risk for health and environment, as well as loss of warranty and liability.

6.3 Warranty and liability

Hardware *ART* warrants the hardware to be free from defects in workmanship and material under normal use and service and in its original, unmodified condition, for a period of 24 months from the time of purchase. The time of purchase is defined as the day when the end-user takes possession of the equipment. If *ART* or any company authorized by *ART* installs the system, the time of purchase is the time of the first installation.
In case of defects during the warranty period, *ART* will repair or replace any defective parts. Replaced parts become property of *ART* .

Software Software supplied either on the tracking-PC or in cameras is furnished on a tested "As Is" basis. *ART* explicitly does not warrant that the software is error (bug) free.

If the users detect bugs, ***ART*** will provide a workaround or bug fix as soon as possible after the notification.

Liability ***ART*** products are not authorized for use in any circumstances where human life might be endangered by malfunction, measurement errors or interrupted operation of the system without written approval of a managing director of ***ART*** .
It is the user's sole responsibility to check the results of the measurement data and to protect any consecutive system against malfunction, measurement errors or interrupted operation of the systems supplied by ***ART*** . Under no circumstances ***ART*** can be held liable for consequential damages or incidental costs, including production downtimes, whether arising from measurement errors, interrupted operation or any other malfunction of the system.

Warranty restrictions All warranty and liability is void, if the system

- is not operated according to the manual,
- shows damages or signs of abuse,
- has been opened by non-authorized people (non-members of ***ART*** and companies not authorized by ***ART***),
- has been modified by the user or any third party,
- has not been used according to the specifications of this manual.

A Technical specifications

☞ **The specifications are subject to change without notice.**

A.1 *SMARTTRACK*

Power supply	
Nominal voltage	12V
Maximal current	0.5A
Maximal power	6W
Ext. power supply	12.2V / 3A / 40W
Protection category	
Ext. power supply	I
Camera	III
Interface connectors	
data	RJ45
synchronization	BNC
power	external
Operating conditions	
Temperature	0 .. 40°C
Relative humidity	5 .. 50%
	non-condensing
Cooling system	active (fan)
Dimensions	
Length	420mm
Width	15mm
Height	54mm
Weight	1470g
Performance	
Frame rate	max. 60fps (adjustable)
IR flash	850nm
Max. tracking distance with 12mm passive markers (F .. focal length in mm).	
@ F = 2.1mm	2.5m
Maximum number of 6DOF targets (simultaneously)	
@ 60fps	4
Field of view (FoV for each lens, horizontal × vertical)	
@ F = 2.1mm	100° × 84°

A.2 Flysticks

	Flystick2	Flystick3
Power supply		
Rechargeable battery	3 standard AAA batteries	lithium battery (850mAh / 3.7V) integrated in the handheld
Continuous operation[1]	at least 10 hours	at least 8 hours
Battery charging duration		
Operation possible with connected charger	no	yes
USB transmitter		
Connection to the PC	USB	USB
Radio range (depending on setup location, e.g. walls)	at least 7m	at least 7m
Radio module		
Type ID	IEEE 802.15.4	IEEE 802.15.4
Frequency	2.4 GHz	2.4 GHz
Transmission power	1	1
Operating conditions		
Operating temperature	0 .. 40°C	0 .. 40°C
Relative humidity	5 .. 50%, non-condensing	5 .. 50%, non-condensing
General features		
Target type	passive markers	passive or active markers (IR-LEDs @ 880nm)
Tracking range (@ 3.5mm focal length)	approx. 4m	approx. 4.5m
Weight	250g	120g
Size	220mm x 180mm x 100mm	245m x 90mm x 75mm

[1] only valid for new batteries

A.3 Overall system

Operating conditions	
Temperature	0 .. 40°C
Relative humidity	5 .. 50%, non-condensing

Compatible shutter glasses	
NuVision APG6000	×
NuVision APG6100	×
NVidia 3D Vision Pro	×, radio synchronization
RealD CE1	×
RealD CE2	×
RealD CE3	×
RealD CE4	-
RealD CE5	×
Volfoni EDGE	×, with Volfoni or NuVision Long-Range Emitter
XPand X103	×, with NuVision Long-Range Emitter

***DTrack2* frontend software**	
System requirements	
- Free disk space	≥ 200MB
- Processor	Intel: ≥ P4 2GHz
	AMD: ≥ K6 1.6Ghz
- RAM	≥ 1GB
Operating systems	Windows XP 32/64 Bit
	Windows 7 64 Bit
	Linux openSUSE 11.3 32/64 Bit
	ubuntu 10.04 32/64 Bit
Settings firewall (remote PC)	
- used ports	50105 (for UDP & TCP)
	50110 (for UDP)

B Radiation Protection for *SMARTTRACK*

B.1 Used Instructions

All calculations refer to German DIN EN 60825-1: "Safety of laser products" ("Sicherheit von Laser-Einrichtungen"), which is correspondingly applied to noncoherent illumination by LEDs. Derived safety instructions correspond to "Durchführungsanweisung zur UVV Laserstrahlung" ("Instructions for using UVV laser radiation") of German "Hauptverband der gewerblichen Berufsgenossenschaften" ("Association of commercial and industrial workers compensation insurance carriers") (October 1995).

B.2 Classification of the LED Flash

The wave length of the LEDs (medium wave length) is in the near infrared at 850nm. It is an expanded source having an area of about 37mm x 37mm.
The emitted radiation is divergent (in contrast to laser radiation). The radiation source is pulsed repeatedly. According to the above-named instructions, three cases have to be considered when using repeatedly pulsed or modulated laser sources of this wave length. Safety instructions will then be determined by the biggest limitation found in these cases:

- exposure of radiation by one single impulse
- average radiation intensity
- radiation by one single impulse with a correction factor for a sequence of impulses.

The intensity of divergent radiation depends on the distance between observer (his eyes respectively) and radiation source.

B.3 Maximum Permitted Exposure of Radiation (MPER)

This chapter shows the "maximum permitted exposure of radiation" (MPER) for the above mentioned cases.

Exposure of Radiation by One Single Impulse Partial result: the exposure of radiation is lower than the MPER value, when ensuring a distance of more than 10cm between IR flash and eye.

Average Radiation Intensity Partial result: the exposure of radiation is lower than the MPER value, when ensuring a distance of more than 10cm between IR flash and eye.

Radiation by One Single Impulse with a Correction Factor for a Sequence of Impulses Partial result: the limitations derived from this case are the most significant. They determine the below listed safety instructions.

B.4 Resulting Safety Instructions

The following diagrams show the minimum necessary distance between IR flash and eyes to fulfill the exposure limitations according to chapter B.3 on page 77.

The values of minimum necessary distances to the external flash are pretty high. During setup, do NOT look into the flash or, better, switch off the external flash!
However, the external flashes are typically mounted behind a projection screen which reduces the radiation intensity by a certain factor depending on the type of screen used. Therefore, only the values for the external flash itself are stated.

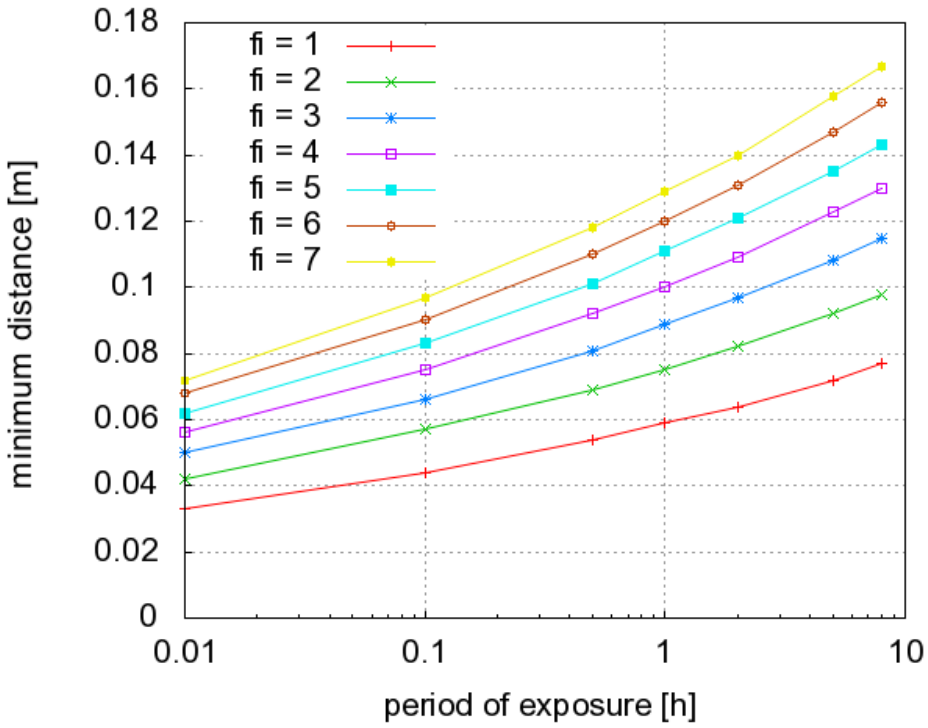


Figure B.1: ***SMARTTRACK*** : Minimum necessary distance at 60Hz and different flash intensities

Example (see figure B.1): Setting a flash intensity of 7 with a duration of exposure of 1 hour, the minimum distance between observer's eye and the ***SMARTTRACK*** has to be at

least 14cm.
Usually the cameras are mounted e.g. at the ceiling of a room; so during normal operation an observer never gets closer to the cameras than the minimum distance. During mounting of the IR cameras attention should be payed to switch on the cameras only for adjustment and not to expose service technicians or other people at a not allowed amount.

If inappropriate use of the IR cameras is possible, employees have to be instructed accordingly and warning notices have to be attached at the tracking cameras.

C Technical Appendix

C.1 Definition of Coordinates and Rotations

C.1.1 Room Calibration

The calibration angle defines origin and axes of the coordinate system. This can be done in three different ways:

Type	longer arm	shorter arm
'*normal*'	+X axis	+Y axis
'*powerwall*'	+X axis	-Z axis
'*powerwall standing*'	-X axis	+Y axis

For example, a room calibration of type '*normal*' would result in a coordinate system like the following:

1. The marker located in the crossing point of the two arms is defining the origin of the coordinate system.
2. The longer arm of the calibration tool defines the +X axis.
3. The shorter arm of the calibration tool defines the +Y axis. (i.e., the tool markers define the X/Y plane.)
4. The Z axis is added in order to give a right-handed coordinate system.

C.1.1.1 Room Adjustment

DTrack2 allows to modify the room coordinate system by specifying these seven values:

- l_x, l_y, l_z for a translational offset (denoted x, y, z in the GUI),
- η, θ, ϕ for a rotation (denoted rx, ry, rz in the GUI).
- s for a scaling factor.

These offsets are defined as a shift and/or rotation and/or scaling of the room coordinate system relative to the original one. Mathematically a point $\vec{x}_{orig}$ in the original room is transformed into a point $\vec{x}_{mod}$ in the modified room coordinate system by:

$$\vec{x}_{mod} = (R^T \cdot \vec{x}_{orig} - \vec{l}) \cdot s$$

where the rotation matrix R is calculated from η, θ and ϕ like defined in section C.1.3.

C.1.2 Body Calibration

During the body calibration ***DTrack2*** is fixing a local coordinate system (body coordinate system) for each rigid body. Both coordinate systems define the later 6DOF output (see chapter C.1.3 on page 81). The calibration can be done in three different ways (to be selected in the menu *Calibrate / Body* of the body calibration):

C.1.2.1 Definition of the Coordinates by the Body itself

Body calibration setting *due to body*:

The body coordinate system is fixed by the markers of the rigid body according to a set of rules:

1. Search the biggest distance between two markers of the rigid body. These two markers (#1 and #2) will define the X axis.
2. Search for a third marker (#3) that has the smallest distance to one of the two markers #1 and #2. The marker that has smallest distance to marker #3 becomes marker #1. It will define the coordinate origin. The other marker will be #2. The positive X axis is directed from marker #1 to marker #2.
3. Marker #3 defines the X/Y plane, together with markers #1 and #2. Marker #3 has a positive Y coordinate.
4. The Z axis is already defined by these rules, resulting in a right-handed coordinate system.

C.1.2.2 Definition of the Coordinates by the Room Coordinate System, with Origin in the Center of the Markers

Body calibration setting *due to room*:

The origin of the body coordinate system is set to the center (center of gravity) of all markers building the rigid body. The axes of the body coordinate system are parallel to the axes of the room coordinate system in the beginning of the body calibration.
I.e., the result of a body calibration will depend on the angular position of the target during calibration. A 6DOF measurement, following calibration without having moved the body, will give the angular coordinates 0° / 0° / 0°.
If the target was moved during calibration, the angular position of the target at the beginning of the calibration will be taken.

C.1.2.3 Definition of the Coordinates by the Room Coordinate System, with Origin in a Marker

Body calibration setting *due to room (zero in marker)*:

A combination of the first two methods. The direction of the axes of the body coordinate system will be set parallel to the room coordinate system in the moment of body calibration - like done with setting *due to room*. The origin of the body coordinate system is given by one marker of the body, according to the rules given for setting *due to body*.

C.1.3 6DOF Results

Position and Orientation

Position and orientation of a target are expressed by an affine transformation $(\vec{s}, R)$ that transforms a vector $\vec{x}$ from the body coordinate system to the room coordinate system:

$$\vec{x}_{room} = R \cdot \vec{x}_{body} + \vec{s}$$

I.e., the coordinates $\vec{s}$ give the position of the origin of the body coordinate system (marker #1 or center of gravity, as described above), measured in room coordinates.
The 3×3 rotation matrix R describes the rotation part of the transformation. The columns of the matrix R are the axes (X, Y, Z) of the body coordinate system, expressed in room coordinates.

Description by Rotation Angles

The rotation matrix can be replaced by three consecutive rotations $R_i(\chi)$ (rotation angle χ, rotation axis i). The angles, as given in the ***DTrack2*** data output, are defined by the equation:

$$R = R_x(\eta) \cdot R_y(\theta) \cdot R_z(\phi)$$

Expressed in trigonometric functions, that means:

$$R = \begin{pmatrix} \cos\phi\cos\theta & -\sin\phi\cos\theta & \sin\theta \\ \sin\phi\cos\eta + \cos\phi\sin\theta\sin\eta & \cos\phi\cos\eta - \sin\phi\sin\theta\sin\eta & -\cos\theta\sin\eta \\ \sin\phi\sin\eta - \cos\phi\sin\theta\cos\eta & \cos\phi\sin\eta + \sin\phi\sin\theta\cos\eta & \cos\theta\cos\eta \end{pmatrix}$$

Note that per definitionem the angles can only have the values:

$$-180^\circ \le \phi \le 180^\circ, -90^\circ \le \theta \le 90^\circ, -180^\circ \le \eta \le 180^\circ$$

Note: rotation angles can show strange behaviour at certain orientations. At particular orientations close to $\theta = \pm 90^\circ$ the other two angles can experience large odd-looking changes.

When connecting ***DTrack2*** to an application, often problems appear caused by different definitions of rotation angles. To avoid that, we recommend to use rotation matrices.

C.1.4 3DOF Data

Besides the tracking of 6DOF bodies, ***DTrack2*** is able to calculate the coordinates of single markers, i.e. markers that can not be recognized as part of a rigid body. The output values are the coordinates of these markers, measured in room coordinates.
In some situations, a rigid body within the measurement volume is (temporarily) not correctly recognized by the software. In these cases, its markers appear as 3DOF objects.
3DOF markers are tracked (as long as possible) and labeled with an ID number. When a 3DOF marker vanishes (or is recognized as part of a 6DOF body), its ID number will not be used any more, as long as the tracking is active.

C.1.5 Flystick devices

DTrack2 is supporting the following input devices:

- Flystick2 and

- Flystick3.

Each of the afore mentioned devices is equipped with buttons (4 - 8) and a small joystick. Input transactions are transmitted wirelessly to the controller and added to the 6DOF tracking result of the Flystick body.
There are two types of output formats available, called `6df` and `6df2` (details see chapter C.2.4 on page 85 and chapter C.2.5 on page 86); they differ in the number of carried input controls. Only the newer `6df2` format is capable of processing analogue values (or controllers) as produced by a joystick. Both formats use the same order of buttons (details see below):

Output Format	Number of Buttons	Order of Buttons	Number of Controllers
`6df`	8 (fix)	"right to left"	—
`6df2`	device dependent	"right to left"	device dependent

C.1.5.1 Flystick2

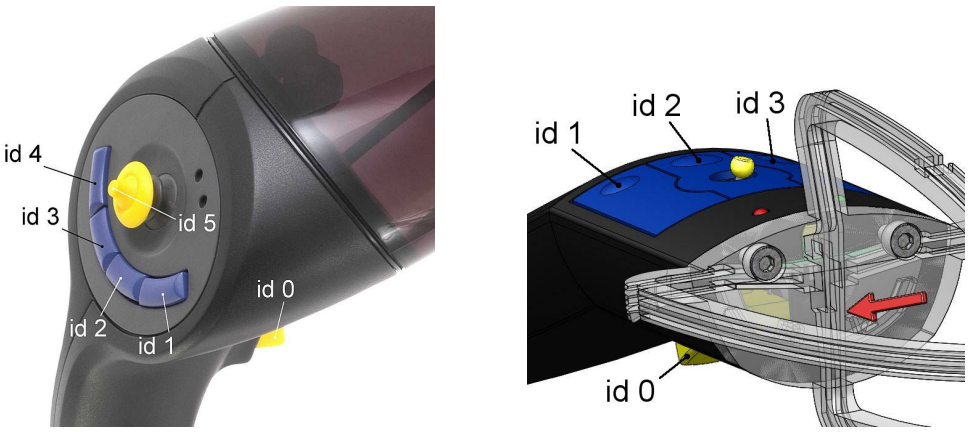
Each Flystick2 is equipped with six switches (buttons) and a small joystick, that produces two analogue values, one for horizontal and one for vertical movement. When using the old output format `6df`, the joystick values are transferred into hat switch actions; two of the buttons cannot be accessed.

Switch	labelled as (in figure C.1)	`6df` Output	`6df2` Output
front switch (yellow)	id 0	code 01 (hex)	button code 01 (hex)
outer right switch on backside (blue)	id 1	code 02 (hex)	button code 02 (hex)
inner right switch on backside (blue)	id 2	code 04 (hex)	button code 04 (hex)
inner left switch on backside (blue)	id 3	code 08 (hex)	button code 08 (hex)
outer left switch on backside (blue)	id 4	–	button code 10 (hex)
switch on joystick (yellow)	id 5	–	button code 20 (hex)
joystick (yellow) to the left	–	code 20 (hex)	first controller up to 1.0
joystick (yellow) to the right	–	code 80 (hex)	first controller up to -1.0
joystick (yellow) up	–	code 40 (hex)	second controller up to 1.0
joystick (yellow) down	–	code 10 (hex)	second controller up to -1.0

C.1.5.2 Flystick3

Each Flystick3 is equipped with four switches (buttons) and a small joystick, that produces two analogue values, one for horizontal and one for vertical movement. When using the old output format `6df`, the joystick values are transferred into hat switch actions.

Switch	labelled as (in figure C.1)	`6df` Output	`6df2` Output
bottom switch (yellow)	id 0	code 01 (hex)	button code 01 (hex)
top right switch (blue)	id 1	code 02 (hex)	button code 02 (hex)
top middle switch (blue)	id 2	code 04 (hex)	button code 04 (hex)
top left switch (blue)	id 3	code 08 (hex)	button code 08 (hex)
joystick (yellow) to the left	–	code 20 (hex)	first controller up to 1.0
joystick (yellow) to the right	–	code 80 (hex)	first controller up to -1.0
joystick (yellow) up	–	code 40 (hex)	second controller up to 1.0
joystick (yellow) down	–	code 10 (hex)	second controller up to -1.0



(a) Flystick2 (b) Flystick3

Figure C.1: Allocation of ID number to the Flystick buttons

C.2 Output of Measurement Data via Ethernet

DTrack2 uses ethernet (UDP/IP datagrams) to send measurement data to other applications. The IP address and the port of the application (and the computer it runs on) can be configured in *Settings* → *Output*.
Each datagram carries all the results of a single measurement, coded in ASCII format. One datagram is sent after each measurement of the cameras, i.e. following the synchronization frequency. The '*send data divisor*' in *Settings* → *Output* offers the possibility to decrease the data output frequency ($f_{output} = f_{sync}/d_{divisor}$).

All data are given in units millimeter (`mm`) or angular degree (`deg` / °).

ART provides free sample source code ('DTrack2SDK', in C++) to receive and parse the output data. Please contact ***ART*** to get it.

A UDP datagram in ASCII format contains several lines separated by CR/LF (hex `0D 0A`). Each line carries data of a specific type and starts with an identifier. In *Settings* → *Output* you may configure which lines or data types should be included in the output:

Identifier	Type of data	enable/disable in
`fr`	frame counter	always enabled
`ts`	timestamp	*Settings* → *Output* ('*ts*')
`6dcal`	additional informations	*Settings* → *Output* ('*6dcal*')
`6d`	standard bodies (6DOF)	*Settings* → *Output* ('*6d*')
`3d`	additional markers (3DOF)	*Settings* → *Output* ('*3d*')
`6df/6df2`	Flysticks (6DOF + buttons)	*Settings* → *Output* ('*6df / 6df2*')

C.2.1 Frame Counter

Identifier `fr`.

This line is always the first one. It carries a frame counter (counting with synchronization frequency).

Example:

```
fr 21753
```

C.2.2 Timestamp

Identifier `ts`.

A timestamp can be added to each datagram. It shows the time at the measurement of this frame, i.e. the time when the infrared flash of the cameras is fired. The timestamp uses the internal clock of the controller, giving back the seconds (with an accuracy of $1\mu s$) since 00:00 UTC[1] (midnight). This implies that the timestamp value is reset to zero when passing midnight (UTC)!

The timestamp typically shows an accuracy of better than $\Delta t_{err} \sim \pm 0.01ms$ with a Synccard2 (used in *ARTTRACK* systems). With a SynccardTP (used in *TRACKPACK* systems) one can only expect an accuracy of $\Delta t_{err} \sim \pm 0.5ms$.

Example:

```
ts 39596.024831
```

C.2.3 Standard 6DOF Bodies

Identifier `6d`.

Measurement data of all tracked standard 6DOF bodies (i.e. all 6DOF bodies except Flysticks, Measurement Tools . . .). Bodies, that are not tracked by the system at that moment, don't appear in the output.

- The first number gives the number of tracked bodies (less or equal to the number of calibrated bodies).
- The data of each tracked body show up in blocks (three consecutive `[]`) like:

  `[id qu]`$[s_x\ \ s_y\ \ s_z\ \ \eta\ \ \theta\ \ \phi]$`[`$b_0\ \ b_1\ \ b_2\ \ b_3\ \ b_4\ \ b_5\ \ b_6\ \ b_7\ \ b_8$`]`

  They contain:

  1. ID number (`id`, starting with 0), quality value (`qu`, unused),
  2. Position (s_i), orientation angles ($\eta\ \theta\ \phi$) and
  3. Rotation matrix (b_i) of the Body's orientation.

  All numbers are separated by spaces (hex `20`). Nine values $b_0 \ldots b_8$ form the rotation matrix R:

  $$R = \begin{pmatrix} b_0 & b_3 & b_6 \\ b_1 & b_4 & b_7 \\ b_2 & b_5 & b_8 \end{pmatrix}$$

  To avoid problems with different definitions of the angles, we recommend to only use rotation matrices.

[1] Coordinated Universal Time = Greenwich Mean Time

Example (one line):

```
6d 1 [0 1.000][326.848 -187.216 109.503 -160.4704 -3.6963
-7.0913][-0.940508 -0.339238 -0.019025 0.333599 -0.932599 0.137735
-0.064467 0.123194 0.990286]
```

C.2.4 Flysticks

Identifier `6df2`.

Note: this format version replaces the older `6df` format (see C.2.5). Use it whenever possible.

The newer format for Flysticks is quite similar to the format of standard 6DOF bodies. It provides tracking data for all Flysticks and other ***ART*** radio devices (see C.1.5):

- The first number after the identifier `6df2` gives the number of defined (i.e. calibrated) Flysticks.
- The second number gives the number of Flystick data, that are following in the line.
- The data of each Flystick show up in blocks (four consecutive `[]`), like:

  `[id qu nbt nct]`$[s_x\ s_y\ s_z]$`[`$b_0\ b_1\ b_2\ b_3\ b_4\ b_5\ b_6\ b_7\ b_8$`]`$[bt_0\ \ldots\ ct_0\ ct_1\ \ldots]$

  The four blocks contain:

  1. ID number (`id`, starting with 0), quality value (`qu`, see below) and the number of available buttons and controllers (`nbt` and `nct`).
  2. Position of the Flystick (s_i).
  3. Orientation of the Flystick, given as rotation matrix (b_i, like standard bodies).
  4. Status of buttons (bt_i, see below) and controllers (ct_i, see below).

- The quality (`qu`) can (so far) just get the values 1.000 or -1.000. -1.000 means that the target of the Flystick is not visible at the moment. Even in that case a Flystick appears in the output data. Then dummy values are used for position (zero) and orientation (zero matrix!). Informations about buttons and controllers are valid as long as the wireless transmission is active.
- When buttons of the Flysticks are pressed the (decimal) numbers bt_i change. They are coded binary (i.e. switch 1 activated = bit 0 set, switch 2 activated = bit 1 set, ...) with a maximum of 32 buttons per bt_i number.

  Note that the number of bt_i numbers in the block can vary with different Flystick hardware! If the device isn't equipped with buttons, the output won't contain any bt_i number!

- Controller elements are transferred into floating point numbers ct_i, reaching from -1.00 to 1.00. In the output line they follow the button informations (one number for each controller).

  Note that the number of ct_i numbers in the block can vary with different Flystick hardware! If the device isn't equipped with controller elements, the output won't contain any ct_i number!

Example (one line) for two devices, one Flystick2 (ID 0) and one Flystick1 (ID 1):

```
6df2 2 2 [0 1.000 6 2][-228.992 270.818 92.561][0.758006 -0.652230 0.004807 -0.651759
-0.757133 0.044271 -0.025236 -0.036691 -0.999008][5 0.13 -1.00] [1 -1.000 4 2][0.000
0.000 0.000][0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000][1 1.00 0.00]
```

C.2.5 Flysticks (Old Format)

Identifier `6df`.

Note: supported just for compatibility. It is recommended to use the newer Flystick format `6df2` (see chapter C.2.4 on page 85) whenever possible.

Refer to chapter C.1.5.1 on page 82 to find out which buttons of the Flystick2 are NOT transmitted when using the old output format `6df`.

This older format for Flysticks is quite similar to the format of standard 6DOF bodies:

- The first number gives the number of defined Flysticks.
- The data of each Flystick show up in blocks (three consecutive `[]`) like:

  $$\texttt{[id qu bt]}[s_x\ s_y\ s_z\ \eta\ \theta\ \phi]\texttt{[}b_0\ b_1\ b_2\ b_3\ b_4\ b_5\ b_6\ b_7\ b_8\texttt{]}$$

  They contain:

  1. ID number (`id`, starting with 0), quality value (`qu`, see below) and button information (`bt`, see below),
  2. Position (s_i) and orientation angles ($\eta\ \theta\ \phi$) and
  3. Orientation (b_i) of the Flystick.
- The quality (`qu`) can (so far) just get the values 1.000 or -1.000. -1.000 means that the target of the Flystick is not visible at the moment. Even in that case a Flystick appears in the output data. Then dummy values are used for position (zero) and orientation (zero matrix!). Informations about buttons are valid as long as the wireless transmission is active.
- When buttons of the Flysticks are pressed the (decimal) number `bt` changes. It is coded binary (i.e. switch 1 activated = bit 0 set, switch 2 activated = bit 1 set, ...).

Example (one line):

```
6df 1 [0 1.000 2][261.103 116.520 41.085 19.6522 -57.3530 116.5992]
[-0.241543 0.968868 -0.054332 -0.482366 -0.168461 -0.859619
-0.842010 -0.181427 0.508039]
```

C.2.6 Additional 3DOF Markers

Identifier `3d`.

The format of additional markers (all markers that don't belong to a 6DOF object) looks like a reduced format of standard bodies:

- The first number is the number of tracked additional markers.

- Blocks (two consecutive `[]`) follow for each marker:

  `[id qu][`s_x s_y s_z`]`

  They contain ID number (`id`, starting with `1`) and a quality value (`qu`, still unused), and the position (s_i).

Example (one line):

```
3d 6 [79 1.000][210.730 -90.669 -108.554] [83 1.000][61.235 -165.625
3.217] [87 1.000][123.633 -107.836 0.110] [88 1.000][212.383 -133.640
77.199] [90 1.000][326.455 -187.055 109.589] [91 1.000][303.185
-239.771 114.861]
```

C.2.7 Additional Informations

Identifier `6dcal`.

Optionally, the number of the calibrated bodies (not only of the tracked ones) can be included in a data set. This is done within an additional line like:

```
6dcal 3
```

Note that this number does not include all calibrated bodies. In particular, it counts the calibrated bodies that show up in the output lines `6d`, `6df` and `6dmt`.

List of Figures

2.1 Principle of optical tracking (stereo vision) . . . 11

3.1 Angular range of visibility . . . 15

4.1 ***SMARTTRACK*** . . . 22
4.2 Attaching the T-piece to the ***SMARTTRACK*** . . . 23
4.3 Welcome screen of ***DTrack2*** with Wake On LAN option . . . 28
4.4 Wake On LAN progress bar . . . 29
4.5 Welcome screen of ***DTrack2*** . . . 33
4.6 ***ARTTRACK*** Controller Selection . . . 34
4.7 Graphical user interface of ***DTrack2*** . . . 35
4.8 Visualization of the synchronization frequency decrease . . . 35
4.9 Monitor 2DOF view menu (e.g. camera 1) . . . 36
4.10 Origin of the room coordinate system (default) . . . 37
4.11 Room calibration settings (e.g. RCS 410) . . . 38
4.12 Marker distances (including numbering) on the angle and definition of room coordinate system . . . 38
4.13 Room calibration process . . . 40
4.14 Room re-calibration dialogue . . . 41
4.15 Body calibration dialogue . . . 42
4.16 Defining the target coordinate system . . . 42
4.17 Import of calibration files . . . 44
4.18 Output settings . . . 51
4.19 A room calibration set consisting of angle and wand . . . 53
4.20 Room adjustment dialogue . . . 54

5.1 Flystick2 . . . 60
5.2 Flystick2 control elements . . . 61
5.3 USB Radio Transceiver2 . . . 62
5.4 Flystick2 - inserting the battery pack . . . 63
5.5 Charging the battery of the Flystick2 . . . 63
5.6 Flystick3 . . . 65
5.7 Flystick3 control elements . . . 67
5.8 Position of the receiver for synchronization . . . 69

B.1 ***SMARTTRACK*** : Minimum necessary distance at 60Hz and different flash intensities . . . 77

C.1 Allocation of ID number to the Flystick buttons . . . 83

List of Tables

1.1 Symbols and their meaning 8

3.3 Standard targets overview 21

4.1 Options for coordinate system definition 39
4.2 ***DTrack2*** menu structure overview 45
4.3 Menu *DTrack2* 46
4.4 Menu *Settings* 46
4.5 Overview of the supported synccard modes 49
4.6 Overview of validated shutter glasses 49
4.7 Tracking settings - Description of the checkboxes 50
4.8 Output identifiers 51
4.9 Flystick settings - Description of the checkboxes 51
4.10 Menu *Calibration* 53
4.11 Menu *Display* 57
4.12 Features of the *Monitor 2DOF view* 58
4.13 Menu *About* 59

5.1 Description of the Flystick2 61
5.2 Status LEDs quick reference 64
5.3 Description of the Flystick3 66

Index

body adjustment, 55

calibration
    body calibration, **41**, 54
    calibration file, 43, **55**
    room calibration, **37**, 53
    room re-calibration, 40
center of gravity, 56
coded flash, 16
configuration management, 46
controller, 25

Data Display, 34
data output, 50
DHCP, 52

Event Display, 34

field of view (FoV), 35, **73**
flash intensity, 47

infrared optical tracking system, 11
interaction device
    Flystick2, 51, **60**
    Flystick3, 51, **65**
IP address, **26**

liability, 71
line of sight, 62

MAC address, 29, **52**
marker
    active marker, 14
    big active flat marker, 15
    big active spherical marker, 15
    passive marker, 13
measurement volume, 39
Monitor 2DOF, 34, **57**
motion capture, 21

radio module, 62
reflex suppression
    automatic, **47**
    manual, **47**
remote PC, 31
retro reflector, 14
rigid body, 17
room adjustment, 54
room calibration set, 37

send data divisor, 50
service and support, 71
Settings, 46
shutter glasses (validated), 49
SMARTTRACK, **22**, 31, 52
software
    DTrack2, **31**, 46
standby mode, 46
static reflex scan, 53
synchronization
    active marker synchronization, 15
    external synchronization, 48
    internal synchronization, 48
    synchronization signal, 25

targets, 17
timestamp, 51, **84**
tracking, 50
trademarks, 2

USB radio transceiver (RT2), 62, 67

virtual point cloud, 39

Wake On LAN (WOL), **28**
wand, **38**, 53
warranty, 71